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Steam-Based PJBL (Project-Based Learning) Model to Improve Critical Thinking Character of Elementary School

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A B S T R A C T

The study aims to determine the effectiveness of the STEAM-based Project-Based Learning (PjBL) model in improving critical thinking skills among elementary school students. This research is based on the issue of low critical thinking ability in Science subjects, particularly because the STEAM approach has not yet been applied in learning. The study was conducted at 1 Pawenang Elementary School as an effort to introduce a learning model that integrates Science, Technology, Engineering, Art, and Mathematics. The STEAM-based PjBL syntax includes formulating essential questions, designing project plans, preparing information-gathering schedules, implementing projects, monitoring activities, testing project outcomes, evaluating learning experiences, and drawing conclusions. This study used a mixed-methods approach with a sequential explanatory design. The quantitative phase examined the effectiveness of STEAM in improving students' critical thinking in Science, while the qualitative phase, through interviews and observations, identified the processes and supporting factors influencing the model's implementation. The results showed that the STEAM-based PjBL model was effective in enhancing students' critical thinking skills. Statistical analysis indicated a significance value of $0.001 < 0.05$, meaning that the STEAM-based PjBL model had a significant positive effect on the improvement of students' critical thinking character.

1. Introduction

The development of education in the 21st century requires students to possess a range of character traits, including critical, creative, collaborative, and communicative thinking skills. These characters provide an essential foundation for students to adapt to changing times and play an active role in solving various life problems rationally and innovatively. In the context of basic education, one of the main challenges faced by educators is how to cultivate students' critical thinking character through learning activities that are not only oriented towards theoretical knowledge, but also provide meaningful and applicable learning experiences. In fact, Indonesia still exhibits low critical thinking skills among elementary school students, as (Fardani, 2024) found that only 14% of elementary school children possess critical thinking skills in the high category, while the rest fall into the middle and low categories. Furthermore, a general survey of critical thinking skills among elementary school students reveals that the results are still low, as Indonesian students are only able to answer questions at levels 1 and 2. Meanwhile, the highest level on PISA and TIMSS questions is level 6, and Indonesian students have not been able to answer questions at this level (Marudut et al., 2020).

Critical thinking involves the ability to rationally examine information, evaluate various arguments, and make decisions based on logical reasoning and reliable evidence. (Prasetyo & Firmansyah, 2022) critical thinking is a cognitive process that involves the ability to identify, examine, and analyze a problem and then devise a solution strategy. Therefore, the teacher's role is that of a facilitator, encouraging students to develop the ability to observe, recognize, analyse, and find solutions to the various problems they face.

One of the learning models that encourages students to think critically is student-centred learning, specifically Project-based learning with a Science, Technology, Engineering, Arts, and Mathematics (STEAM) approach, which has emerged as an innovative strategy in responding to these challenges. (Bybee, 2013) emphasizes that STEAM can enhance active student involvement and foster higher-order thinking skills. The application of the STEAM approach, in conjunction with the Project-Based Learning (PBL) model, offers students opportunities to learn through projects that require creativity, collaboration, and the application of knowledge to solve real-world problems. Learning should not only focus on the final result, but also emphasize the process of thinking and finding solutions (Widiantari, 2016; Azka et al., 2024).

The Project-Based Learning (PjBL) model is a learning approach that focuses on students as the center of learning activities, while the teacher acts as a facilitator and motivator. Through this model, students are encouraged to think critically, actively solve problems, and construct and apply the knowledge they acquire in the form of projects relevant to the learning context (Asih et al., 2024; Aldyza & Danil, 2025). Through these experiences, students are expected to develop critical thinking skills, curiosity, responsibility, and problem-solving skills both independently and collaboratively (Zulfa et al., 2024; Syadiah & Indonesia, 2020). Thus, the implementation of the STEAM-based project learning model not only deepens students' understanding of scientific concepts but also contributes to character building and the development of scientific mindsets.

Based on the stated condition, research was conducted at 1 Pawenang elementary school, District Bojong, Purwakarta Regency, with the subject being the student class V in the eye lesson of Natural Sciences (IPA). Select the school and subject. This is based on the problem of ability, specifically the ability to think critically, for students who have not yet appeared in class V. Although, in a way, ideally, the ability to think critically is required when considering the learning process, specifically for students on a school basis. Therefore, the need is to increase students' ability to think critically through the implementation of more active, creative, and contextual learning models. Students in Class V are considered to have their own readiness in the cognitive stage of operational concrete, enabling them to analyze, compare, and evaluate simple phenomena that occur around them. Based on these conditions, this research was conducted at 1 Pawenang elementary school, Bojong District, Purwakarta Regency, with fifth-grade students in the Natural Sciences (IPA) subject as the research subjects. The selection of this school and subject was based on the problem of students' critical thinking skills, which had not yet developed in fifth-grade students.

Meanwhile, ideally, critical thinking skills are essential in the learning process, particularly for elementary school students, as these skills enable learners to actively engage with learning content and solve problems meaningfully (Suryana et al., 2022; Pasca & Waluya, 2024). However, the development of such skills requires intentional efforts through the implementation of learning models that are more active, creative, and contextual, allowing students to explore ideas, ask questions, and construct understanding based on real-life experiences. At the fifth-grade level, students are considered to have reached sufficient cognitive readiness within the concrete operational stage, which allows them to think logically about concrete situations, analyze relationships, compare information, and evaluate simple phenomena occurring in their surroundings. Therefore, integrating appropriate learning approaches at this stage is crucial to optimally foster students' critical thinking skills and support their overall cognitive development.

Thus, this study aims to analyse the application of the project-based STEAM learning model in enhancing the critical thinking skills of fifth-grade students at 1 Pawenang Elementary School by integrating science, technology, engineering, arts, and mathematics into collaborative, inquiry-oriented projects. Through the implementation of this model, students are actively engaged in problem-solving activities that encourage them to explore real-world phenomena, formulate questions, analyse information, and construct solutions creatively and logically. As a result, the learning process becomes more meaningful, interactive, and transformative, shifting from teacher-centered instruction to student-centered experiences. This approach not only strengthens students' conceptual understanding of scientific content but also systematically cultivates their critical thinking character, equipping them with essential cognitive and reflective skills as a foundation for facing the complex challenges of 21st-century life.

2. Methodology

The research method employs a mixed-methods approach, combining quantitative and qualitative methods with a sequential explanatory design. The purpose of the Sequential Explanatory Mix method is to gain a more comprehensive understanding of quantitative data, incorporating numbers and statistics, and qualitative data, which produces a broader and deeper view (Creswell, 2017). A quantitative pre-experimental one-group design is employed to assess the effectiveness of the STEAM learning model in enhancing students' critical thinking skills before and after its implementation in Science subjects in elementary schools.

While qualitative data collection, including interviews and observations, is used to measure how critical thinking changes in students after using the STEAM model in Science subjects. This research was conducted at 1 Pawenang Elementary School, Bojong District, Purwakarta, in the odd semester of the 2025/2026 academic year. The research subjects consisted of 32 fifth-grade students. The selection of subjects used purposive sampling, based on the consideration that students at this grade level are generally expected to have reached the developmental stage appropriate for engaging in learning activities that foster critical thinking through project-based learning. Quantitative data were analysed statistically by calculating the average score and percentage improvement. A t-test was employed to examine the differences in results before and after the treatment.

Data collection also involved interviews with six students. Categories were determined based on their critical thinking profiles, with two students categorized as low, two as medium, and two as high, according to the observation questionnaire. Qualitative data were analysed using the Miles and Huberman model (Miles et al., 2014), which includes three stages: data reduction, data presentation, and conclusion drawing. The results of both analyses were then integrated to gain a comprehensive understanding of the impact of integrating the Project-Based Learning and STEAM learning models on enhancing the critical thinking skills of fifth-grade students at Pawenang Elementary School.

3. Results and Discussion

Quantitative data analysis in this study aims to evaluate the quality of the learning process through the integration of the Project-Based Learning (PBL) STEAM model in enhancing students' critical thinking skills by measuring learning outcomes and observable improvements objectively. Meanwhile, qualitative data analysis serves to complement and reinforce the quantitative findings by exploring learning processes in greater depth through observations, interviews, and documentation. This qualitative approach provides contextual insights into students' engagement, learning experiences, and responses to the implemented learning model, thereby offering a more comprehensive understanding of the effectiveness and practicality of the application-based learning model in supporting critical thinking development.

Stage Preparation

Evaluate the quality of learning in the STEAM-based project-based learning model, where stage preparation started with compiling device learning and tests, which involve critical thinking through observation sheets for students. Research results indicate that the validation of the device learning results is categorized as very good, so it can be concluded that all device learning is valid and can be used in this Study.

Instrument used in the implementation of a group learning experiment with a STEAM-based project-based learning model for students in the 5th grade of an elementary school. Compilation syntax started from integrating the project based learning model with STEAM in Science subjects refer to the theories of George Lucas and Georgette Yakman with rationality integration of the Project Based Learning (PjBL) model with STEAM (Science, Technology, Engineering, Art, and Mathematics) approach to subjects Grade V science lessons are based on needs For develop ability think critical, creative, and collaborative student through experience meaningful learning.

Science learning at the school base not only aims for students to understand scientific concepts, but also to enable them to apply their knowledge in real life. The PjBL Model provides students with the opportunity to study through demanding projects, exploration, problem-solving, and working in a team (Nurtriana et al., 2024). The temporary STEAM approach emphasizes the integration of various disciplinary knowledge in one learning activity, allowing students to establish the relevance between science, technology, engineering, art, and mathematics in a real-world context (Yakman, 2008). The integration of both creates an environment that is challenging and interactive learning, allowing students not only to understand science concepts in a general theoretical sense, but also to apply them through creative and innovative activities. Thus, this integration of the PjBL model and the STEAM approach is expected to increase motivation for lifelong learning skills at the level and foster character in students from an early age.

The syntax is designed in accordance with the planning program learning curriculum 13, with the theme "Changing Energy", and competence-based. Explain various forms of energy and describe their conversion, as well as their applications in daily life. The compilation of STEAM-integrated Project-Based Learning (PBL) begins with the Study of theory and analysis to meet the learning needs of students and science objectives. Syntax Then arranged based on steps main PjBL according to (Lucas, 2005) namely: (1) determine question contextual basis; (2) designing project with integrate STEAM elements; (3) compose timetable activities; (4) monitoring the process and progress project; (5) assess learning products and processes; and (6) carrying out reflection together students. With this order, science learning becomes more meaningful, creative, and encourages critical thinking and collaborative skills in students. As for the syntax, STEAM-based project-based learning is used as follows:

Stage Implementation

Stage implementation in this study encompassed a systematic sequence that began with the design of learning activities based on the syntax of the selected learning model, ensuring that each instructional step was aligned with the intended learning objectives and students' developmental characteristics. This was followed by the design and application of learning model syntax within instructional media, integrating a STEAM-based project-based learning approach that actively engaged 5th-grade elementary school students in meaningful, inquiry-driven projects.

Through these projects, students were encouraged to develop critical thinking character by analyzing problems, collaborating, experimenting, and creating solutions that connected science, technology, engineering, arts, and mathematics. The implementation stage was concluded with a comprehensive evaluation of learning activities to assess both the learning process and outcomes, particularly the extent to which students' critical thinking character improved as a result of the STEAM-based project-based learning activities. The syntax of the project-based learning model is as follows:

Table 1. The syntax of the STEAM project-based learning model

Stage PjBL	Learning objectives	Teacher and Student Activities	STEAM Integration	Output
Orientation to the problem (Determine the Question's fundamental)	Students can identify problem energy in their daily life and formulate a project question.	The teacher shows a video/ picture about the utilisation of energy (solar, wind, electricity). Fishing teacher student with Question: "Where does energy come from?" and "What are the consequences? "If energy finished?" 3. Students discuss and create a project question: "How can methods make tools simple with energy alternatives?"	S (Science): to know draft energy. A (Arts): responding to visual stimuli.	Question projects that will be answered at the meeting, furthermore
Planning project	Students can design project ideas for simple energy alternatives.	4. The teacher divides the students into groups. 5. Every group choose a type of project (eg, car, electric power, mini windmill The teacher guides in compilation design: materials, tools, and steps. - Students draw design tools on paper	T (Technology): determines tools and materials. E (Engineering): A simple design tool. M (Mathematics): estimating size and material	Draft design project energy alternative.
Compilation schedule and collection information	Students can arrange time for artistry projects and collect information from supporters.	Students make timetable projects on paper and cardboard. - Students look for information from books, the internet, or an interview with the source person.	S&T (Science & Technology): digging draft energy. A (Arts): designing a timetable project.	Project schedule and supporting data.

		- The teacher guides on election-relevant information.		
Implementation and creation of a project	Students can make a tool simple by utilising the principle of energy alternatives.	Students create tools in accordance with a design (e.g., a car, a power balloon, a windmill, a mini wind turbine, a stove, a power Surya). - The teacher monitors, gives guidance and ensures safe work. Students conduct a trial of tools and note the results	(Science): applying draft energy. E (Engineering): making a tool. M (Mathematics): measuring distance/time results test. A (Arts): decorating tool.	Product tool energy alternative simple.
Presentation and evaluation results of the project	Student capable of presenting and explaining the project results.	Every group presents tools in front of the class. Teachers and other friends give input and questions. - The teacher assesses the use of the rubric creativity, function, and cooperation	A (Arts): composing appearance tool. S&T (Science & Technology): explains the principle of the Work tool.	Presentation projects and assessment results. Work. Reflection and conclusion
Reflection and conclusion	Students are able to reflect on learning experiences and conclude energy concepts.	The teacher guides reflection: "What do you learn from this project?" - Students write a personal journal reflection about learning energy and conservation energy. The teacher emphasised the importance of renewable energy.	S (Science): to conclude the draft energy. M (Mathematics): analyse results measurement. A (Arts): writing reflection, creative.	Journal reflection, individual, and class conclusion.

Table 1. This alternative energy-themed project-based learning (PjBL) is designed to help students understand energy concepts through hands-on activities that integrate the STEAM approach. The activity begins with an introduction to the problem of energy sources and their impacts, followed by students formulating a project question. Next, they design a simple alternative energy-based device, organize a schedule, gather information, and build the product according to the design under the teacher guidance. Afterward, students present their project results and reflect on the learning experience. This learning combines Science in understanding energy concepts, Technology and Engineering in tool creation, Mathematics in measurement, and Arts in design and presentation.

Description of the Pre Test Results: Students of 1 Pawenang Elementary School after Implementing the STEAM-based Project-based Learning Model for Improving Critical Thinking Character

Based on research results conducted by researchers at 1 Pawenang Elementary School before the pretest, researchers observed the teacher's approach to using the learning method in class and how students responded during ongoing learning. The selected location is the 5th grade of 1 Pawenang Elementary School, Bojong, Purwakarta Regency. Based on the results of reflection, researchers find that students develop a problem-related character and think creatively when using the STEAM project-based learning model. There is a problem that students develop creative thinking skills and solve problems, mainly due to a lack of teachers implementing varied learning models.

During the pretest stage, an observation-based questionnaire was administered to assess the critical thinking skills of Grade V students using the critical thinking indicators proposed by Ennis (1993), which consist of five dimensions and were designed to capture students' actual critical thinking performance before the implementation of the STEAM-based Project-Based Learning (PjBL) model. The pretest data functioned as baseline data to determine students' initial critical thinking abilities before treatment. Data analysis of both pretest and posttest results was conducted using SPSS (Statistical Package for the Social Sciences) version 29 to facilitate accurate and systematic data processing. To evaluate the effectiveness of the STEAM-based PjBL model in improving students' critical thinking skills, a paired sample t-test was employed to examine whether there was a statistically significant difference between pretest and posttest scores. Before hypothesis testing, prerequisite analyses, including normality and homogeneity tests, were conducted to ensure that the data met the assumptions required for parametric statistical testing, with the normality of the pretest data of Grade V students at 1 Pawenang Elementary School examined using SPSS version 29.

The results from the normality test analysis are presented in Figure 1. A normality test was performed to verify the known normal distribution of the data. Data normality test in Study This using the Shapiro-Wilk test. The criterion for testing data normality is that if the mark probability is more than $\alpha = 0.05$, then the data is normally distributed (Winarsunu, 2006). The results of the normality test calculation, using SPSS (Statistical Package for the Social Sciences), were carried out on the data analysis of the pretest and post-test. Using the SPSS (Statistical Package for the Social Sciences) version 29 program simplifies the process of processing and calculating research data. In testing the effectiveness of the STEAM-based Problem-Based Learning model on improving students' thinking abilities, researchers first conduct a series of prerequisite tests before carrying out a paired t-test (Paired Sample t-test).

Based on the results of the normality test conducted using the Shapiro–Wilk method on the pretest data of 32 students, the obtained significance value (p-value) was 0.121. This value exceeds the established threshold of 0.05, indicating that there is no significant deviation from a normal distribution. Consequently, the pretest data can be considered normally distributed and fulfill the assumption of normality required for parametric statistical analysis. With this assumption satisfied, further inferential statistical procedures, particularly the paired sample t-test, can be appropriately applied to examine whether there is a significant difference between students' pretest and posttest scores.

Description of the Post Test Results: Students of 1 Pawenang Elementary School after Implementing the STEAM-based Project-based Learning Model for Improving Critical Thinking Character

Test data were collected after the given treatment, using a project-based learning model with STEAM-based activities carried out over 2 weeks, comprising a total of 6 meetings. Each teacher meeting provided stimulating learning experiences through a project-based learning model, specifically a STEAM-based approach, for 5th-grade students at 1 Pawenang Elementary School. The approach encompassed preparation/planning, core learning, and evaluation. The results of the analysis were processed using SPSS 29, with data normality tests conducted to assess the normality of the study data using the Shapiro-Wilk test. The criteria for testing data normality are that if the p-value is more than $\alpha = 0.05$, then the data is normally distributed (Winarsunu, 2006). Based on the normality test results using the Shapiro-Wilk test on the posttest data, the criticality of a sample size of 32 students obtained a significance (Sig.) of 0.832. This value is greater than 0.05 ($0.832 > 0.05$), so it can be concluded that the posttest data are normally distributed. The data meet the requirements for analysis using statistical tests, such as the paired sample t-test, to determine if there is a significant difference between pretest and posttest results of students' critical thinking ability.

Based on Levene's Test of Homogeneity of Variances (Figure 3), the obtained p-value of 0.154 is greater than 0.05, indicating that the variance between the data groups is homogeneous. This shows no significant difference in variance between the tested groups, fulfilling the assumption of homogeneity, making the data suitable for further analysis, such as a t-test or ANOVA. These results indicate that the STEAM-based Project-Based Learning (PBL) model has uniform variance between groups (Pallant, 2020). In the hypothesis test calculation, parametric analysis was used with a confidence level of 0.05. If Sig. (2-tailed) < 0.05, Ho is rejected, and Ha accepted; if Sig. (2-tailed) > 0.05, Ho is accepted, and Ha is rejected.

The histogram results (Figure 1) indicate that the pretest data on students' critical thinking ability are symmetrically distributed around a mean score of 73.37, with no extreme outliers, forming a pattern that closely resembles a bell curve. This distribution suggests that the data are relatively balanced and do not show significant deviations. These findings are supported by the results of the Shapiro–Wilk normality test, which produced a significance value of 0.121 ($p > 0.05$), indicating that the data are normally distributed in accordance with the criteria proposed by Ghozali (2018). Since the normality assumption has been fulfilled, the pretest data are suitable for analysis using parametric statistical tests, particularly the paired sample t-test, to examine differences in critical thinking ability before and after the treatment.

Table 2. Normality Test Pretest-Posttest

	Kolmogorov–Smirnov			Shapiro–Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest Critical Thinking	122	32	.200*	947	32	121
Posttest Critical Thinking	103	32	.200*	981	32	832

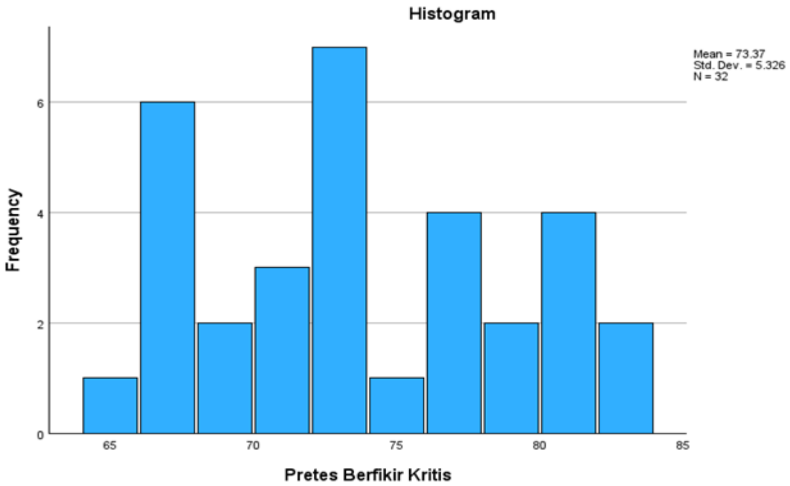

Figure 1. Normality Test Graph Pretest and Posttest

Table 3. Homogeneity Test: Pretest and Posttest

		Levene Statistic	df1	df2	Sig.
Model (PjBL-based STEAM)	Based on Mean	1.893	8	15	136
	Based on Median	814	8	15	602
	Based on Median and with adjusted df	814	8	6.773	614
	Based on Trimmed Mean	1.808	8	15	154

Testing Hypothesis Research

After confirming that the research data were normally distributed and homogeneous, the subsequent step in the analysis was hypothesis testing. Prior to the implementation of the treatment, the data analysis focused on pre-test results obtained from assessments administered to students before the application of the STEAM-integrated Project-Based Learning model. These pre-test data were collected to identify students' initial levels of critical thinking skills and to serve as a baseline for comparison with post-treatment outcomes. By analyzing the pre-test results, the researchers were able to ensure that any changes in students' critical thinking abilities could be attributed to the implementation of the STEAM-integrated Project-Based Learning model rather than to pre-existing differences among participants. The following is the result of the pretest and posttest that have been done:

Table 4. Result data pretest and posttest

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest Critical Thinking	73.38	32	5.326	942
	Posttest Critical Thinking	83.81	32	5.114	904

The data shows that the pre-test score was 73.38. After finding the results of the pretest, the next step is to conduct the post-test and evaluate the effectiveness of the treatment in increasing critical thinking character traits. The results of the post-test scores obtained are 83.81. Analysis data improvement refers to data obtained based on the change results from the pre-test to the post-test, which researchers get from the results of testing that has already been conducted for the Grade 5 students Elementary School 1 Pawenang. Based on the results of the second test, the researchers then look for mark gain, that is, the difference in marks, which describes the change in marks before and after the activity learning with the treatment of the Project-based learning Model of STEAM integration for increasing critical thinking. The difference value from the pre-test to the post-test was 10.43, indicating a change from the pre-test to the post-test.

Hypothesis testing was conducted to examine the effect of the Project-Based Learning (PjBL) model on STEAM integration in fostering students' character thinking; however, the results indicate that there is currently no sufficient evidence to confirm a significant influence. The analysis employed a paired sample *t*-test, which is an appropriate statistical method for comparing research data collected before and after the implementation of a treatment. This test was chosen to determine whether there was a statistically significant difference in the mean scores prior to and following the application of the PjBL model. The findings from this analysis suggest that the observed changes in mean values were not significant enough to support the proposed hypothesis, indicating that the implementation of the Project-Based Learning model did not produce a measurable improvement in character thinking through STEAM integration within the scope of this study. The following hypothesis test results using the paired sample t-test:

Table 5. Hypothesis Testing

		Paired Differences					t	df	Significance	
					95% Confidence Interval of the Difference				One-Sided p	Two-Sided p
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper				
Pair 1	Pretest Critical Thinking – Posttest Critical Thinking	-10.438	2.793	494	-11.445	-9.430	-21.138	31	< .001	< .001

Based on the table above, the hypothesis test results are found using the following field criterion, which is based on the best estimate. If the difference is greater than zero, making. If the sig value (2-tailed) is greater than 0.05, then H0 is accepted, and H1 is rejected. Likewise, on the contrary, if the sig value (2-tailed) < 0.05, then H0 is rejected and H1 is accepted. Based on the results of the Paired Sample t-test in the table above, the obtained t value = -21.138 with degrees of freedom (df) of 31 and the value significance (p) of < 0.001. Because the p-value is smaller than 0.05 ($p < 0.05$), there is a statistically significant difference between the pretest and posttest in terms of students' thinking ability. The Project-Based Learning (PBL) model was implemented. The average difference value (Mean Difference) of -10.438 indicates that the posttest score is higher than the pretest score, which means that the STEAM-based Project-Based Learning (PBL) model is effective in increasing students' ability to think critically.

Thinking Character Description critical of students Grade V of 1 Pawenang Elementary School

This study employed a qualitative research approach using in-depth interviews to explore changes in students' critical thinking skills before and after the implementation of the STEAM-based Project-Based Learning (PjBL) model. The participants consisted of six students who were purposively selected to represent varying levels of academic ability, namely two students with low ability, two with medium ability, and two with high ability. Data were systematically collected through classroom observations, observation sheets, checklists, and questionnaires to capture students' learning processes and responses comprehensively. The collected data were then analyzed descriptively to identify patterns and differences in critical thinking abilities across the different ability categories, providing a detailed understanding of how the STEAM-based PjBL model influenced students' critical thinking development.

Student A (low) initially gave short, socially influenced answers, e.g., "Because my friends do too," showing limited logic. After the renewable energy project, he provided simple logical explanations, e.g., "We use windmills because wind can turn the propeller so it can produce electricity," showing improvement in analyzing cause and effect. Student B (low) was passive and lacked confidence, but after collaborative project activities, he participated actively, stating, "Now I bravely shared my opinion, because in the project we were ordered to find our own ideas and work in a group." Student C (medium) initially offered limited reasoning, e.g., "Because the battery is finished," but later considered multiple causes, e.g., "Maybe not only the battery, but also the cable is not enough," demonstrating critical analysis. Student D (medium) struggled to connect theory with practice but improved, linking concepts to real-life experiences, e.g., "If we push car toys, that style. However, if we add a battery, it's the energy that makes it go on its own," reflecting enhanced critical thinking (Ramdayani et al., 2024).

Student E (high) already displayed reflective and evaluative thinking, e.g., "According to me, this is not yet efficient because we have not yet counted on its energy," and further developed integrated STEAM reasoning after the project, e.g., "This design is effective because, in a way, technology is simple, the ingredients are easy to obtain, and, scientifically, it can explain the conversion of energy." Student F (high) showed curiosity and experimental interest but initially lacked structure. After the STEAM project, he became more systematic, noting, "I am now more careful, take notes of every step, so that I can know what is wrong?" (Wasahua, 2021; Wayudi et al., 2020; Rusmansyah et al., 2024).

Interview results indicate that STEAM-based Project-Based Learning positively impacted critical thinking across all categories. Low-ability students improved in courage, opinion, and simple logic; medium-ability students enhanced cause-and-effect analysis; and high-ability students strengthened reflective, evaluative, and systematic thinking. This learning model effectively develops critical thinking character through active, collaborative, contextual, and experiential learning, aligning with STEAM principles that promote flexible and innovative problem-solving (Yakman, 2019; Perignat & Katz-Buonincontro, 2019).

4. Conclusion

Based on the results of the research and the discussion that has been described about the effectiveness of the STEAM-based project-based learning model for increasing character and Critical Thinking in Grade V Students of 1 Pawenang elementary school in the Science Subject: There is an influence of the Project-Based Learning Model STEAM on the improvement of critical thinking in students in Grade V of 1 Pawenang elementary school. The findings of the study revealed that the statistical analysis produced a significance value of 0.001, which is lower than the threshold of 0.05. This indicates that the STEAM-based project-based learning model has a significant positive effect on enhancing students' critical thinking abilities. In other words, the implementation of this learning approach effectively contributes to the development of students' critical thinking character through integrative and experiential learning processes. Qualitative analysis through interviews to describe the critical thinking character of fifth-grade students of 1 Pawenang Elementary School before and after the implementation of the STEAM-based Project-Based Learning model. Six students with different ability levels were sampled. The results showed an increase in critical thinking skills in all categories. Students with low abilities became more courageous in expressing opinions and thinking in simple logic, students in the middle category were better able to analyze cause and effect, while students in the high category showed reflective, evaluative, and systematic abilities. Overall, the implementation of STEAM-based Project-Based Learning has proven effective in developing students' critical thinking character through active, collaborative, and contextual learning activities.

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