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Integration of PJBL, STEAM, and Learning Tool Development in Improving Students' Critical Thinking Skills

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ABSTRACT

Objective: This research aims to explore improving critical thinking skills by applying Project Based Learning (PjBL) based on the STEAM (Science, Technology, Engineering, Arts, and Mathematics) model in Renewable Energy material at 1st Trowulan State Vocational School. The main aim of this research is to assess the effectiveness of STEAM-based PjBL in improving students' critical thinking skills at 1st Trowulan State Vocational School Trowulan. **Method**: The research method used was an experiment with a One Group Pre-test and Post-test design. The research subjects comprised 25 students of Class X Computer and Network Engineering 1 (X-1) and 26 students of Class X Computer and Network Engineering 1 (X-2). During the research, students were given PjBL-based learning with a STEAM approach to Renewable Energy material. Before and after learning, students are tested using a pre-test and post-test to measure the increase in their critical thinking skills. **Results**: The analysis shows that implementing PjBL-based learning based on STEAM is efficacious in improving students' critical thinking abilities. A comparison of pre-test and post-test scores on Renewable Energy material shows a significant increase in students' critical thinking abilities. **Novelty**: The novelty of this research lies in its new contribution to the field of education. The combination of the PjBL and STEAM approaches in learning Renewable Energy makes a new contribution to preparing students to face real-world challenges that continue to develop. Critical thinking ability is an essential skill in facing the challenges of the 21st century, and this research shows that this approach is practical in developing it. Integrating critical thinking skills into STEAM-based learning provides essential added value in education.

INTRODUCTION

The research explores the impact of implementing the STEAM-based Project Based Learning (PjBL) model on developing critical thinking skills in secondary school students. This study will investigate the influence of the STEAM-based PjBL model on students' critical thinking abilities through a comprehensive research approach that includes observation, interviews, and quantitative data collection (Yani & Mulia, 2023). It will also involve a long-term analysis, evaluation student creativity, and a comparison with conventional teaching methods (Syamson & Nurdin, 2021).

The research intends to provide practical recommendations for developing a STEAM-based PjBL curriculum that enhances critical thinking skills in secondary school students. This will involve measuring improvements in critical thinking skills before and after implementing the model, assessing the role of teachers in its implementation, examining the impact of learning materials on renewable energy, and determining the model's compatibility with the national curriculum (Rusmansyah et al., 2023). In summary, this research offers guidance for creating more effective educational practices that equip students with strong critical thinking skills to address the challenges of the modern world (Halim, 2022; Saphira & Prahani, 2022).

RESEARCH METHOD

This research employed a Pre-Experimental method, specifically the "One-Group Pretest-Posttest" design, conducted at 1st Trowulan State Vocational School Mojokerto from September to October 2023. The study focused on two classes, namely X-1 and X-2, comprising students in the Computer and Network Engineering program during the 2023/2024 academic year, emphasizing science and technology subjects, including Renewable Energy material. Sixty-two students participated in this research, 25 in X-1 and 26 in X-2. The "One-Group Pretest-Posttest" design was chosen to assess the impact of implementing the STEAM-based PjBL model on student learning. It involved measuring students' knowledge and understanding both before and after the intervention to determine any significant changes in their understanding as a result of the STEAM-based PjBL learning approach. This design allowed for the evaluation of the learning intervention's effectiveness. The post-test is illustrated in Table 1.

Table 1. One-group pretest-posttest design.

Pre-test	Treatment	Post-test
Q1	X	Q2

(Agustin, 2020)

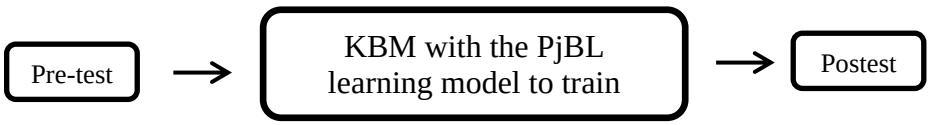

Figure 1. Research flowchart.

Based on Figure 1, this research consists of three main stages. The first stage is planning, where a STEAM-based learning plan is prepared that focuses on PjBL, as well as the assessment materials that will be used. The second stage is the implementation stage, where students actively participate in the STEAM-based learning process focusing on PjBL. Finally, the data analysis compares students' pre-test and post-test scores to evaluate the learning impact. The research data consists of two main components, namely critical thinking tests and student responses to STEAM-based learning that focuses on PjBL. Critical thinking tests cover knowledge and competency, while critical thinking attitude questionnaires and student feedback sheets measure student satisfaction and motivation toward learning methods (Suryaningsih & Nisa, 2021). Data collection techniques involve written tests and questionnaires.

Data analysis was carried out using various statistical methods, such as the paired t-test to compare scores before and after treatment, as well as the N-gain test to measure increases in student understanding. A Likert scale questionnaire was used to understand students' attitudes towards learning (Ramadhana, 2021). Overall, this research aims to evaluate the impact of STEAM-based learning that focuses on PjBL on students' critical thinking skills through pretest-posttest data analysis and measuring student satisfaction with learning methods. The Likert scale used is presented in Table 2.

Table 2. Likert scale scores.

Criteria	Score	
	Positive (+)	Negative (-)
Strongly Agree	4	1
Agree	3	2
Disagree	2	3

Strongly Disagree	1	4

Calculate the Percentage of Student Responses for Each Indicator using the following formula:

$$\text{Percentage (\%)} = \frac{Number\ of\ respondent\ answers}{Maximum\ score}\ x\ 100\%$$

The percentages calculated from student questionnaire responses are then represented in the scoring criteria as presented in Table 3.

Table 3. Representation of score.

Percentage	Criteria
76.00% - 100.00%	Highly interesting
51.00% - 75.00%	Interesting
26.00% - 50.00%	Moderately interesting
00.00% - 25.00%	Not interesting

RESULTS AND DISCUSSION

Results

In this study, a pre-test was carried out before students received learning treatment to evaluate their critical thinking abilities. After the learning treatment, students are given a critical thinking test a second time (Nardiyanti, 2022; Rusmansyah et al., 2023). The increase in students' critical thinking in Project Science subjects with renewable energy material is calculated using the normalized gain (N-Gain) formula based on pre-test and post-test data, and a paired t-test is carried out (Teddy, 2023; Desy, 2023; Dina, 2023). A comparison of the average scores between students' pre-test and post-test critical thinking is presented in Table 4.

Table 4. Recapitulation of student's science literacy scores.

	Pretest	Posttest
Minimum Value	20.00	70.00
Maximum value	90.00	90.00
Mean value	55.00	80.00

Based on Table 4, there is a significant increase in students' critical thinking scores between the pre-test and post-test. The minimum score on the pre-test of 20 increased to 90 on the post-test, while the maximum score increased from 70.00 to 90.00. The average critical thinking score of students also experienced a significant increase, namely from 55.00 on the pre-test to 80.00 on the post-test.

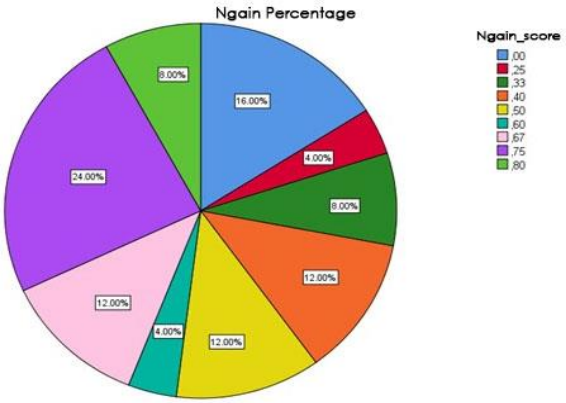

Figure 2. N-Gain calculation graph for pre-test and post-test.

In interpreting the increase in critical thinking using the normalized gain (N-Gain) formula, it can be concluded that there is a moderate increase in students' critical thinking skills after going through the learning treatment (Dina, 2023). This can be seen in the graph shown in Figure 2. Based on the results of the paired t-test carried out in this study, it was found that there was a significant difference between students' pre-test and post-test critical thinking scores (Agustin et al., 2020; Lasmana et al., 2020; Ramdhani et al., 2020). This can be concluded based on a significant p-value of 0.00. Therefore, the null hypothesis (H0) is rejected, and the alternative hypothesis (H1) is accepted. This means that the learning treatment provided has a significant influence on improving students' critical thinking skills (Nasution, 2023; Rofiq & Mashuri, 2021). Table 2 shows the results of the paired t-test, which includes the mean, standard deviation, and p-value. The mean pre-test score was -21.00, with a standard deviation of 13.12.

Table 2. The results of paired t-test.

	Mean	Standard Deviation	Sig. (2-tailed)	Conclusion
Pre-test - Post-test	-21.00	13.12	.000	Reject H_0

These results indicate that before the learning treatment, students' critical thinking scores tended to be low. However, after going through the learning treatment, the post-test score experienced a significant increase. This finding is consistent with previous research by Kamala., (2023), which shows that the Project-Based Approach can improve critical thinking skills. Thus, the learning treatment provided in this research effectively improves students' critical thinking skills in Project Science subjects with renewable energy material.

Overview of Improvement in Each Critical Thinking Indicator

In this research, there are several critical thinking indicators used, namely interpretation, analysis, evaluation, inference, and explanation (Rosmalinda et al., 2021; Hidayati et al., 2021). The results of the N-Gain calculation for the interpretation indicator are presented in Figure 3.

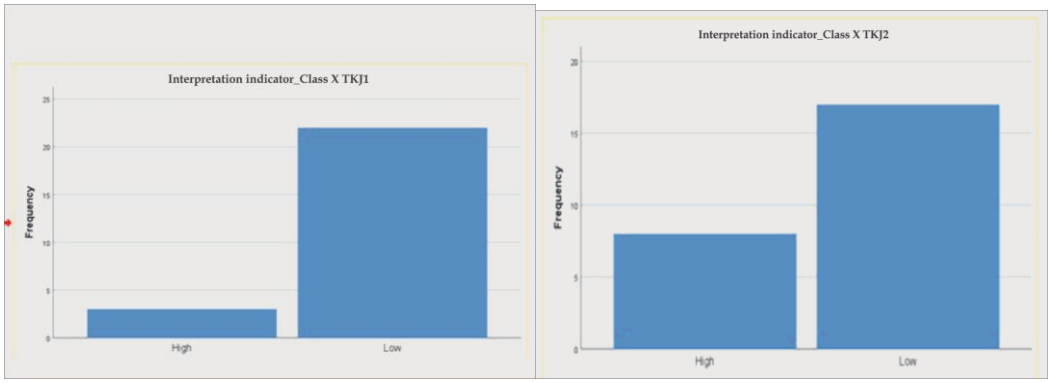

Figure 3. N-Gain calculation results for interpretation indicator.

Yusuf's (2018) research with 25 students using N-Gain showed that 22 students showed a slight improvement in interpretation, and three students were significant. However, the average N-Gain value is low, indicating a need for improvement. The majority of students need to experience increased critical thinking in interpretation. More effective teaching methods are needed to improve interpretation. These findings emphasize the importance of measuring students' critical thinking skills and improving interpretation (Davidi et al., 2021). The results of the N-Gain calculation for the interpretation indicator are presented in Figure 4.

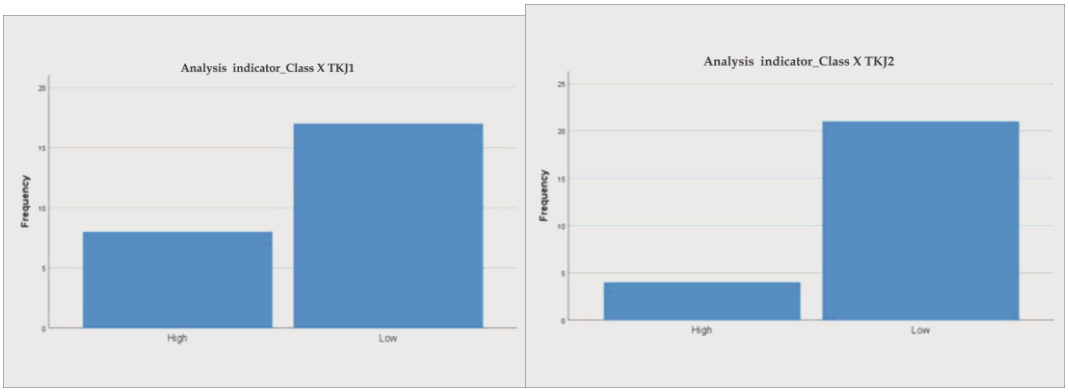

Figure 4. Displays data from N-Gain calculation results for analysis indicator.

Research by Zani et al. (2018) using N-Gain assessed the improvement of the analytical skills of 25 students. As a result, 17 students rose low, and eight rose high. The majority are not much improvement; the average N-Gain is moderate. This emphasizes the importance of educational institutions focusing on developing students' analytical skills with effective teaching and evaluation methods (Ghina, 2023). The results of the N-Gain calculation for the interpretation indicator are presented in Figure 5.

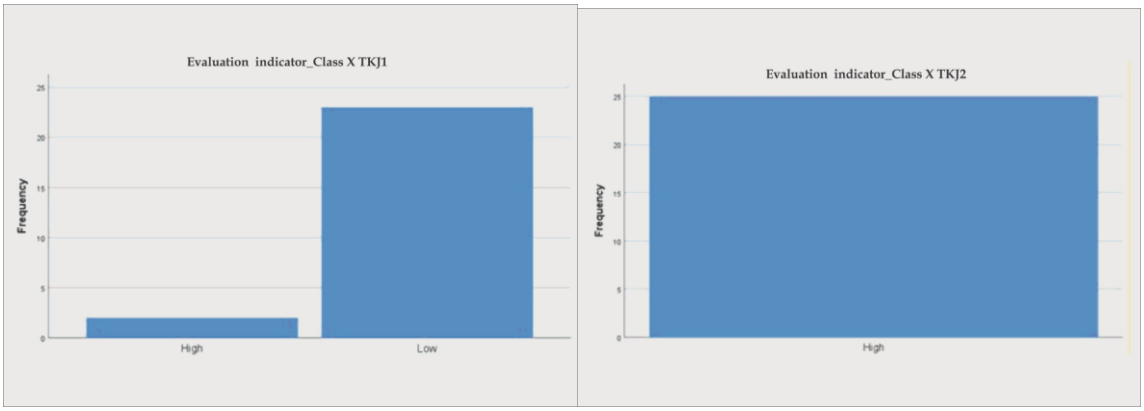

Figure 5. Displays data from N-Gain calculation results for evaluation indicator.

Muliani & Nurpatri's (2019) research on 25 students found that 23 students experienced low analytical improvement, and only two students experienced high improvement, especially on question number 6. The average N-Gain for analytical skills was in the moderate improvement category. These results highlight the importance of educational institutions' focus on developing students' analytical skills through appropriate teaching methods and practical evaluation (Suryana & Ismi, 2019). Consistent effort and a dedicated learning approach are necessary to prepare students for real-world challenges that demand strong evaluation skills. The results of the N-Gain calculation for the interpretation indicator are presented in Figure 6.

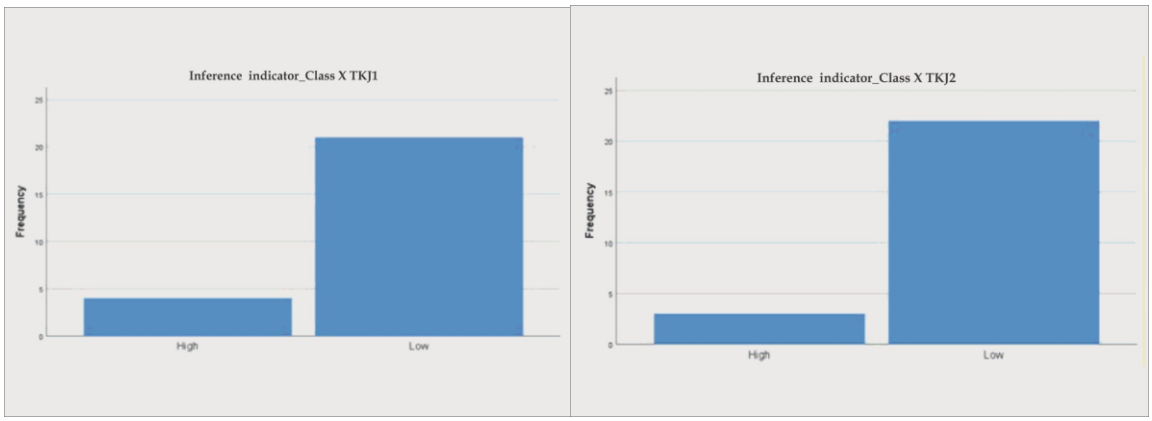

Figure 6. Displays data from N-Gain calculation results for inference indicator.

Prasetyo et al.'s study. (2020) used N-Gain to assess improvements in critical thinking related to interpretation, especially inference abilities, in 25 students. As a result, 21 students experienced minimal improvement, and only four experienced significant improvement. Most students (21 of 25) experienced minimal improvement in inference, and the average N-Gain score was in the low category. These findings emphasize the importance of educational institutions using more effective teaching methods and improving students' critical thinking training regarding interpretation and inference skills. This will help students analyze information, understand it more deeply, and make appropriate conclusions based on existing evidence. The results of the N-Gain calculation for the interpretation indicator are presented in Figure 7.

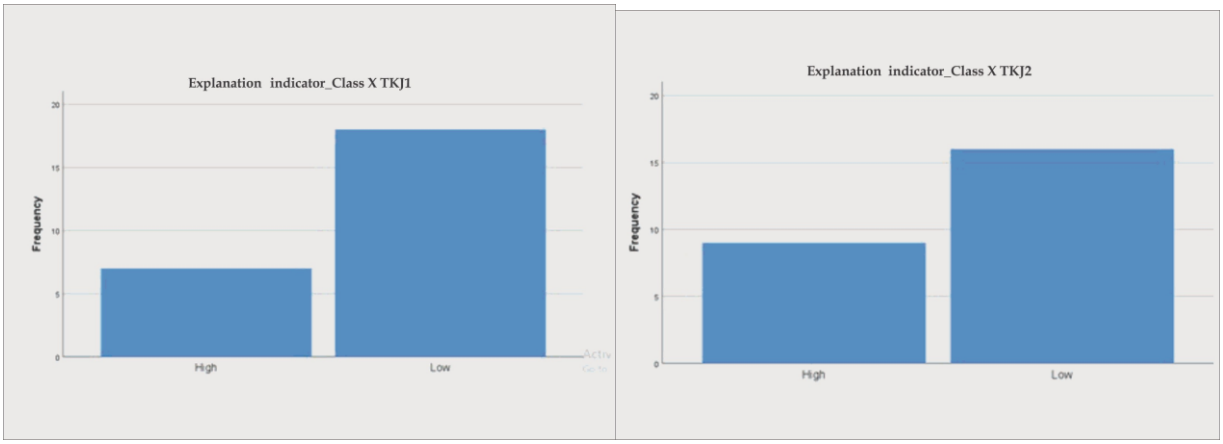

Figure 7. Displays data from the N-Gain calculation results for the explanation indicator.

Hotimah (2020) study used N-Gain to assess improvements in the explanation abilities of 25 students. As a result, 16 students experienced minimal improvement, while nine experienced significant improvement. Most students experienced minimal improvement, and the average N-Gain score for explanation ability was in the low category. These results demonstrate the importance of developing students' explanation abilities through more effective teaching and evaluation methods. Additional efforts and appropriate learning approaches are needed to improve students' explanation abilities, which are essential skills in critical thinking and communication.

Discussion

Student responses to PjBL-based learning with a STEAM approach

Results from questionnaires administered to 25 students after implementing Project-Based Learning (PjBL) for critical thinking with the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach have been analyzed. The questionnaires assessed students' responses to the learning process, focusing on interpretation, analysis, evaluation, inference, and explanation. The findings suggest that most students responded positively to PjBL-based critical thinking learning with the STEAM approach (Ramadhana, 2021). Of the 25 students, 10 reported feeling motivated and satisfied with the learning process. Moreover, 15 students felt supported in understanding and connecting the learning material to the real-world context using PjBL with the STEAM approach.

These results indicate the success of implementing PjBL-based critical thinking learning with the STEAM approach in creating a motivating and satisfying learning environment for most students. It also highlights how this approach helps students comprehend and apply the material to real-life situations (Dywana & Airlanda, 2020). The overwhelmingly positive response from students demonstrates the effectiveness of the PjBL approach and the integration of STEAM in promoting critical thinking skills (Anisa, 2022; Supriyatin et al., 2023). Students feel engaged in the learning process and receive the necessary support to enhance their critical thinking abilities (Khoiriyyah et al., 2022). Overall, nearly all students expressed satisfaction with the implementation of PjBL-based critical thinking learning with a STEAM approach, indicating its efficacy in motivating and supporting students to think critically and connect the material to their real-life experiences (Mu'minah, 2021; Murthi et al., 2022).

The analysis of questionnaires given to 25 students after implementing Project Learning (PjBL) with the STEAM approach to critical thinking showed positive responses from most students. Of the 25 students, 10 reported high levels of motivation, while 15 students felt supported in connecting learning material to the real world. This positive response shows the success of STEAM-based PjBL in creating a learning environment that motivates and supports students in developing critical thinking skills (Dini, 2022). These results provide a solid basis for considering further application of this approach in educational contexts focusing on critical thinking and STEAM skills (Hasanah et al., 2021).

CONCLUSION

Fundamental Finding: This research concludes that implementing the Project Based Learning model with the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach significantly enhances students' critical thinking abilities. Moreover, students responded positively to this method, confirming its effectiveness. This suggests that integrating the STEAM-based project learning approach in education can significantly benefit students' critical thinking skills**. Implication**: These findings hold significant implications for education. Enhancing critical thinking through Project Based Learning with STEAM demonstrates its value in fostering intellectual development. Teachers and policymakers should consider incorporating this approach into the curriculum. The positive student feedback highlights the importance of creating an engaging and motivating learning environment that encourages interactivity. Additionally, students recognizing the real-world relevance of their learning underscores the importance of providing contextual and applicable content in the curriculum. In conclusion, this research underscores the need for more contextual, interactive, and critical thinking-focused education to prepare students for the future. **Limitation**: In summary, this research demonstrates the success of the Project Learning model with the STEAM approach in improving students' critical thinking skills, as evidenced by medium-level average N-Gain scores and positive t-test results. Students' positive responses further emphasize the method's effectiveness in enhancing motivation, comprehension, and real-world connections. This highlights the importance of integrating this approach into educational curricula to advance critical thinking skills and overall educational quality. The STEAM-based project approach shapes a more relevant and meaningful educational future. **Future Research:** Future studies could explore contextual variables and their impact on the effectiveness of the Project Based Learning approach with STEAM in developing critical thinking. Comparative studies with other teaching methods, long-term evaluations, and curriculum development are also pertinent areas for research. These avenues can provide deeper insights into this method for enhancing education.

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