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Boosting Students Critical Thinking in High School: Project- Based Learning on Global Warming

Elsi Oktaviyanti[1], Dedeh Kurniasih[1*], Dini Hardiati[1].Zahratun Nufus[2]

[1] *Muhammadiyah University of Pontianak*
[2] *SMAIT Al-Fityan Kubu Raya*
dedeh. kurniasih@unmuhpnk.ac.id

Abstract. *Critical thinking skills that are low in chemistry learning represent an issue that requires special attention from teachers. These skills are crucial for preparing a generation capable of competing globally and directly impacting student learning outcomes. This study aims to determine the effect of the project-based learning model on high school students' critical thinking skills concerning global warming material. This quantitative research employs a quasi-experimental design with a one-group pretest-posttest approach. The population of this study consists of 62 students from class X Science at SMAIT Al-Fityan Kubu Raya. Through purposive sampling techniques, class X B, consisting of 33 students, was selected as the sample. Pretest-posttest questions were used as data collection tools to assess students' critical thinking skills and learning outcomes, while observation sheets were used to evaluate student activities during the learning process. Data analysis included normality tests, homogeneity tests, paired sample T-tests, and n-gain analysis. The results showed that students' critical thinking skills, based on the average pretest score of 48.7, increased to 84.65 in the posttest. Therefore, project-based learning is very effective as a teaching model for enhancing students' critical thinking skills regarding global warming.*

Keyword*: Critical thinking skills, global warming, project-based learning*

INTRODUCTION

21st-century skills require that students have various abilities, including critical thinking skills (Anagün Assoc, 2018; Baroya, 2018; Island et al., 2021). Critical thinking skills emphasize the capacity for analysis, identification, evaluation, compiling information, and designing new ideas to make decisions regarding an issue (Ningsih et al., 2021; Pratiwi et al., 2023; Syarifah et al., 2018; Utami et al., 2017). These skills are crucial as individu equip students to compete in the global arena.(Gunawan et al., 2022; Jamaluddin et al., 2020; Nuryanti et al., 2018). In chemistry learning, critical thinking skills are crucial due to the complex nature of chemistry concepts that require deep understanding and clear reasoning (Nuraeni et al., 2019; Sariati et al., 2020; Sulastry et al., 2023). The percentage of learners' critical thinking skills in chemistry lessons remains inadequate, with chemical bonding materials only reaching 34.5% (Khoirunnisa & Sabekti, 2020), electrolytic and non-electrolytic solutions at 43.5% (Ningrum & Ratman, 2021), electron configurations at 31.0% (Rezki et al., 2022), and reaction rates at 36.87% (Setianingsih & Roshayanti, 2022). This situation indicates the need for training and development of critical thinking abilities in chemistry instruction (Fernanda et al., 2019). Chemistry is a subject that studies natural phenomena closely related to life (Fadhilah & Yenti, 2019), one of which is the event of global warming. Global warming is the result of the earth's ecosystem imbalance caused by rising temperatures, the atmosphere, oceans, and land (Faturrohman, 2023). This phenomenon arises due to the increase in greenhouse gases such as CH_4 (methane), N_2O_2 (dinitrogen dioxide), NO_2 (nitrogen dioxide), and SF6 (sulfur hexafluoride). These gases absorb solar radiation, causing an increase in the Earth's temperature (Rahmadania, 2022).

According to data from the World Meteorological Organization, the Earth's temperature increases by 1.1°C each year, triggering a climate crisis (Mcgrath, 2020). This change has widespread impacts on the environment and human life, ranging from floods, threats to food security, rising sea levels, the spread of diseases, to an increase in extreme weather events(Septaria et al., 2019; Susilawati, 2021). This issue is highly relevant to the Sustainable Development Goals (SDGs), particularly Goal 13, which focuses on taking action to combat climate change (Fuso Nerini et al., 2019; Irhamsyah, 2019). Teaching this material in schools not only helps students understand scientific phenomena but also directly develops their critical thinking skills in problem-solving while encouraging them to actively contribute to the achievement of the SDGs through real-world actions (Putri et al., 2023; Ryantini et al., 2022). This aligns with the educational vision that emphasizes the importance of youth in responding to global challenges and becoming agents of change in protecting the environment for the future. Based on the chemistry learning objectives of Phase E in the Merdeka Curriculum, students are expected to respond to global issues, including global warming, and actively contribute solutions through skills such as identifying problems, proposing ideas, designing solutions, making decisions, and communicating them in the form of simple projects (Kemendikbudristek, 2022).

Observations at SMAIT AI-Fityan indicate a need to cultivate students' critical thinking abilities in the study of chemistry. During the study process, only 37% of students were actively involved, while 63% were less active. Interviews with the chemistry teacher at the school revealed that the teacher applied a problem-based learning model with a scientific approach designed to stimulate students' critical thinking skills through problem-solving. However, many students still struggle with identifying problems, analyzing information, developing solutions, and providing quality answers that meet the teacher's expectations. These facts suggest that there are issues with students' critical thinking skills, which need to be developed. An alternative solution proposed to address these issues is to employ an educational model that can effectively train students' critical thinking skills.

Learning that can enhance critical thinking skills and make students actively participate is Project Based Learning (PjBL) (Nawangsari et al., 2022; Sumardiana et al., 2019) . PjBL emphasizes students' ability to learn independently through problem-solving and provides opportunities for students to produce projects (Astra et al., 2019; Nababan et al., 2023; Selasmawati & Lidyasari, 2023; Syakur et al., 2020). The learning process using this model includes the following steps: fundamental questions, project planning, creating a project schedule, monitoring project progress, testing results, and evaluating project outcomes (Herlina, 2021). According to previous research, this learning model can enhance students' critical thinking skills on electrochemistry topics through projects such as constructing Volta cells using fruits and conducting copper plating (Zahroh, 2020). On colloid topics, this model serves as an alternative instructional approach strategy that can train students' critical and creative thinking skills with a percentage of 81% (Andini & Rusmini, 2022). On redox reaction topics, it improves students' critical thinking skills by 82.85% (Ambar et al., 2022). The topic of reaction rate through the liquid organic fertilizer production project resulted in a critical thinking ability percentage of 85.4% (Sumarna & Rushiana, 2023).(Sumarna & Rushiana, 2023).

Based on the facts and literature review, PjBL has significant advantages in enhancing critical thinking skills. This study is important because it supports Goal 13 of the Sustainable Development Goals (SDGs), aligns with the learning outcomes of the independent curriculum, and directly contributes by providing an effective alternative learning model to improve students' critical thinking skills. Therefore, this study aims to investigate the critical thinking skills of high school students using the PjBL model on the topic of global warming.

METHOD

This study employs a quantitative method with a quasi-experimental design and a one-group pretest-posttest approach. The research population comprises 62 students from grade X IPA at SMAIT AI-Fityan Kubu Raya. The selection of a single group in this study is based on the separation of male and female classes at the school, which makes it difficult to implement a design with two groups that share similar demographic characteristics and conditions. The research sample was selected using purposive sampling, involving 33 students from class X B. The research design (Sugiyono, 2022) is presented in Table 1.

Table 1. One group pretest-posttest design

Group	pretest	Treatmen	postest
Eksperiment	Q_1	X	Q_2

Information:

Q_1 : Pretest score (before treatment)
Q_2 : Posttest score (after treatment)
X : Treatment
Q_1 x Q_2 : impact on students' critical thinking abilities

The PjBL model consists of several stages: 1) defining fundamental questions, 2) designing the project, 3) scheduling project implementation, 4) monitoring project progress, 5) evaluating project outcomes, and 6) conducting evaluation (Herlina, 2021), as shown in Figure 1.

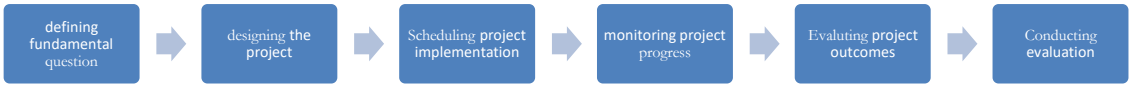


Figure 1. Steps of Project-Based Learning

The pretest and posttest questions used are in essay form to assess students' learning outcomes and critical thinking skills. These questions are designed based on higher-order thinking levels aligned with cognitive levels C4, C5, and C6, which include abilities in analysis, evaluation, inference, and creation (Kamila & Taufiki, 2021). Additionally, an observation sheet is used to evaluate student activities during the learning process. This observation sheet includes indicators of critical thinking skills that are assessed, such as the ability to provide simple explanations, build basic skills, draw conclusions, provide additional explanations, and strategize and formulate tactics (Khasani et al., 2019), as shown in Table 2.

Table 2. Critical Thinking Indicators

Critical thinking indicators	Critical thinking sub-indicator
Provide a simple explanation	Analyzing arguments Focusing question
Developing fundamental abilities	Observe and analyze the findings
Conclude	Create and review values resulting from considerations
Make further explanations	Identify assumptions
Formulate plans and methods	Formulate alternative solutions Deciding on a Course of Action

Validation is conducted to ensure that the instruments and learning tools used are appropriate for use. Equation 1 (Arikunto,2009) is used to calculate the validation score from the validators, which serves as the basis for determining the validation result criteria, as presented in Table 3.

$$p = \frac{\sum x}{\sum x_1} \times 100\ \% \qquad (1)$$

Information:

P : The percentage being sought.
$\sum x$: The total score of respondents' answers.
$\sum x_1$: The total ideal score.

Table 3. Classification of Validation Results

Percentage	Validation Criteria
76-100	Highly suitable
56-75	Suitable
41-60	Adequate
21-40	Less suitable
<20	Not suitable

Reliability testing is conducted to determine the level of test reliability, so the validated questions must be pilot-tested first. The tests used in this study are in the form of essay questions, calculated using the alpha formula (Arikunto, 2009) presented in Equation 2. The criteria for reliability testing are shown in Table 4.

$$r_{11} = \left(\frac{n}{n-1}\right)\left(1 - \frac{\sum \acute{o}_i^2}{\acute{o}_i^2}\right) \qquad (2)$$

Information:

r_{11} : The reliability sought
n : Number of questions
$\sum \acute{o}_i^2$: Total variance of scores for each item
$\acute{o}_i^2$: Total variance

Table 4. Reliability criteria

Interval koefisien	Criteria
0,800-1,000	Very high
0,600-0,899	High
0,400-0,599	Currently
0,200-0,399	Low
0,000-0,199	Very low

Student scores are calculated using Microsoft Office Excel based on Equation 3 and classified according to Table 5 (Arikunto, 2016). Equation 2 is used to calculate the mean and standard deviation of the scores and students' critical thinking skills.

$$\text{Score} = \frac{\text{Total score obtained}}{\text{Maximum score}} \times 100 \qquad (3)$$

Table 5. Guidelines for Students' Critical Thinking Abilities

Percentage	Criteria
81%-100%	Excellent
66%-80%	Good
56%-65%	Currently
41%- 55%	not enough
0%-40%	Very less

The Microsoft Office Excel application is used to calculate student scores based on Equation 4 and categorize them according to Table 6. Equation 2 is used to calculate the mean and standard deviation of both student scores and critical thinking skills.

$$S=\sqrt{\frac{\sum X^2 \frac{\sum x^2}{n}}{n-1}} \qquad (4)$$

Information:

$\sum x$: Total student scores

$\bar{x}$: $\frac{\sum x}{n}$

N : The number of students

$\bar{x}$: Average student score

Data analysis using SPSS 26.0 for Windows was conducted to examine whether there is a notable disparity in students' critical thinking skills before and after implementing PjBL, as summarized in Table 6. The testing criteria include normality tests to check data distribution, homogeneity tests to ensure variance uniformity across groups, and paired t-test to evaluate the mean difference in critical thinking skills before and after PjBL implementation. The n-gain values indicate the improvement in critical thinking skills measured using the PjBL model. The calculation formula is shown in Equation 5, with assessment criteria outlined in Table 7.

Table 6. Test Criteria

Statistical analysis	Assessment criteria
Shapiro-wilk test (normality)	Data is considered non-normal if the level of significance (sig) is <0.05. Conversely, if the significance value (sig) is >0.05, then the data is deemed to have a normal distribution.
F-test (Homogeneity)	Data is considered homogeneous if the significance level (sig) is less than 0.05. However, if the significance level (sig) is greater than 0.05, the data is considered to show non-homogeneous distribution.
T-test	If the significance value (sig) < 0.05, Alternative hypothesis is supported wihe null hypothesis is refuted whereas if the significance value (sig) > 0.05, Ha is denied and Ho is approved

$$<g>=\frac{\text{Posttest Score - Pretest Score}}{\text{Maximum Score - Pretest Score}} \qquad (5)$$

Table 7. Standards for n-gain score

Nilai <g>	Criteria
n-gain>0,7	Tall
0,7<n-gain>0,3	Currently
n-gain<0,3	Small

FINDINGS

Research device test validation results

Based on the validation results from three validators on the research instruments, which include the teaching module, student worksheets, the critical thinking skills observation rubric, and the project assessment rubric, the summary of the validation results is presented in Figure 1

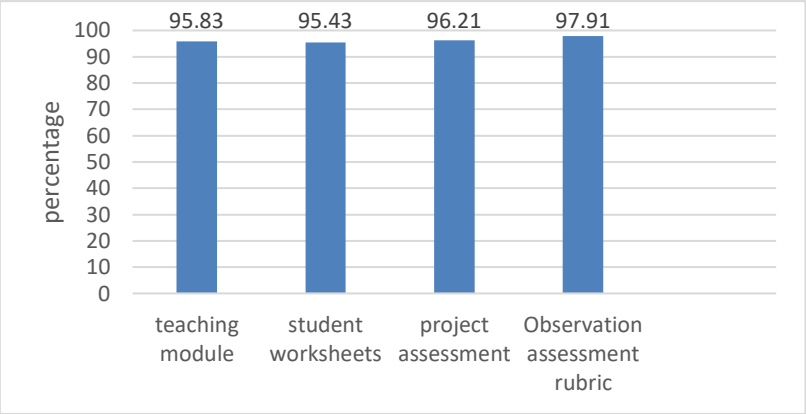


Figure 1. Diagram of validation results of research tools

Based on the data presented in Figure 1, it is evident that the observation assessment rubric received the highest validation score, with an average of 97.9%. This indicates that the rubric is highly suitable for assessing student performance during the learning process. Project assessment ranked second with a validation score of 96.21%, confirming that this tool is effective in evaluating students' project work. The teaching module received a validation score of 95.83%, placing it third in terms of validity, indicating that the module meets the necessary validity standards for use in learning. The Student Worksheet obtained a slightly lower validation score than the other learning tools, at 95.43%, but its validity level remains very high, demonstrating that the student worksheets is still valid and appropriate for use as a learning aid.

Research instrument validation test results

The research instruments that have been validated in this study include pretest and posttest questions. The validation results of this instrument are presented in Figure 2.

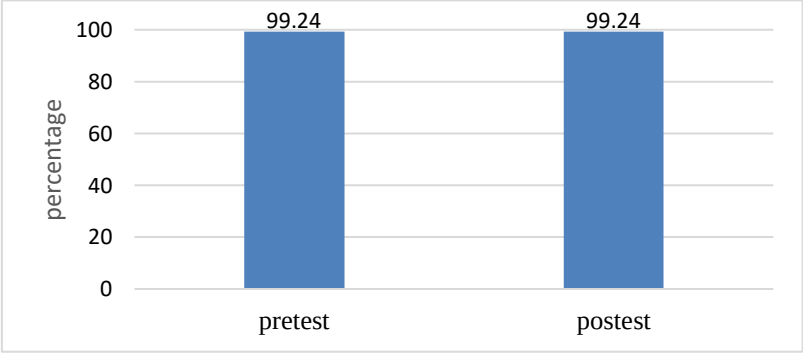


Figure 2. Diagram of research instrument validation results

Based on the data in Figure 2, it is shown that both the pretest and posttest received the same validation score of 99.24%. This figure indicates that the instruments have a very high level of validity. These results demonstrate that the instruments have met the required validity standards to consistently and effectively measure students' abilities both before and after the learning process.

Reliability Test

The reliability test aims to ensure the consistency and stability of the research instruments in measuring what they are intended to measure. The result of the reliability test for the research instruments produced a reliability coefficient of 0.63. This value indicates that the instruments used have a high level of reliability.

Results of Critical Thinking Skills Observation

In this study, the measurement of students' critical thinking skills on the topic of global warming includes several indicators, such as: providing basic explanations, developing basic skills, drawing conclusions, offering further explanations, and devising strategies and tactics. The results of this study are presented in Figure 3

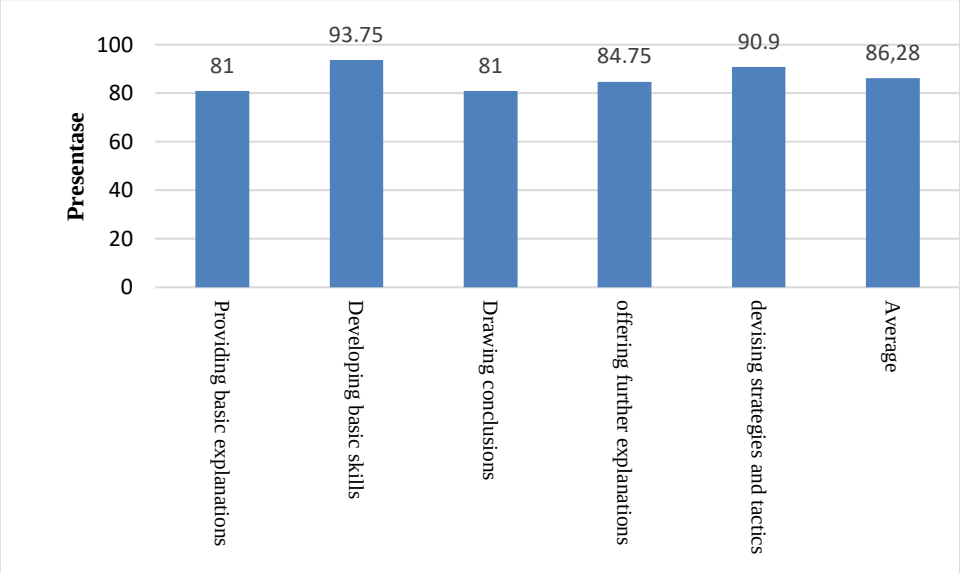


Figure 3. Graphic of Observation Results of Critical Thinking Skills

Based on the presented data, it can be concluded that students performed well in all aspects of critical thinking skills assessment. The students' best performance was in the aspect of "building basic skills" with a score of 93.75 and "developing strategies and tactics" with a score of 90.9. The lowest scores were in the aspects of "providing basic explanations" and "drawing conclusions," both receiving a score of 81. The critical thinking observation skills assessment sheet provided includes indicators of critical thinking skills, which are a series of intellectual activities involving the processes of identifying, analyzing, and evaluating information obtained through observation and learning experiences. This process is used as a basis for making appropriate decisions (Solihah, 2019). The PjBL model supports the development of students' critical thinking skills as described below

Providing basic explanations

This indicator refers to students' ability to clearly and structurally explain concepts, ideas, or topics they have learned. The PjBL model in "providing basic explanations" is implemented through tasks that involve conveying fundamental information, where students are required to present an organized explanation of the topics they have studied, such as concepts of global warming. Student performance in this aspect scored 81 points, indicating a high result. This aligns with the statement (Rusminiati et al., 2015), where PjBL supports critical thinking skills by encouraging students to engage in independent investigation and provide explanations based on data and facts, as well as being able to filter relevant information to construct strong arguments.

Building basic skills

This indicator focuses on the development of basic skills through the ability to identify and understand information, which is a crucial foundation for students in facing more complex learning challenges. Student performance in this aspect reached 93.75 points, indicating a very high score. These findings align with the statement (Radianto & Wijaya, 2018) that PjBL involves tasks that

encourage students to conduct research, collect data, and organize information systematically. (Fitriani et al., 2019) also support the view that this process helps students develop essential basic skills in problem-solving and decision-making.

Drawing Conclusions

The indicator for drawing conclusions focuses on students' ability to make logical, data-driven conclusions after analyzing information. This trains students to summarize research findings and discussions in a systematic and structured manner. Student performance in this activity scored a high 81 points. This finding aligns with (Zahroh, 2020), who stated that applying the conclusion-drawing indicator in the PjBL model provides students with opportunities to sharpen their skills in summarizing and effectively evaluating information, an integral part of critical thinking.

Providing further explanation

The indicator "Providing Further Explanation" emphasizes students' ability to develop additional and deeper explanations related to topics or ideas they have studied. Student performance in this aspect scored 84.74 points, showing a high result. This score reflects students' ability not only to understand basic information but also to expand their explanations with relevant details and examples on global warming issues. For instance, students were able to explain in greater depth the causes of rising global temperatures, the impact of polar ice melting, and the negative effects on ecosystems and humans. This is consistent with findings (Sutamrin & Khadijah, 2021), who noted that PjBL successfully leveraged the learning process to develop critical thinking skills through exploration and ideas, enabling students to provide explanations in both discussions and presentations.

Developing strategies and tactics

This indicator refers to students' ability to plan and implement effective strategies or tactics for solving problems. Student performance in this aspect scored 90.9 points, indicating a very high level of ability. This score reflects students' ability to plan and execute effective strategies or tactics to address the problems they faced. This aligns with the opinion of (Indratno et al., 2018), who explained that PjBL learning encourages students to be active in making decisions, designing solutions, and taking responsibility for seeking and managing information.

Pretest and Posttest Results

This research administered pretest and posttest questions that had been validated by experts. The critical thinking skills assessed in these questions encompass higher-order thinking levels, involving C4, C5, and C6, which include activities such as analysis, evaluation, inference, and creation (Kamila & Taufiki, 2021). The pretest and posttest results of the students are presented in Figure 4.

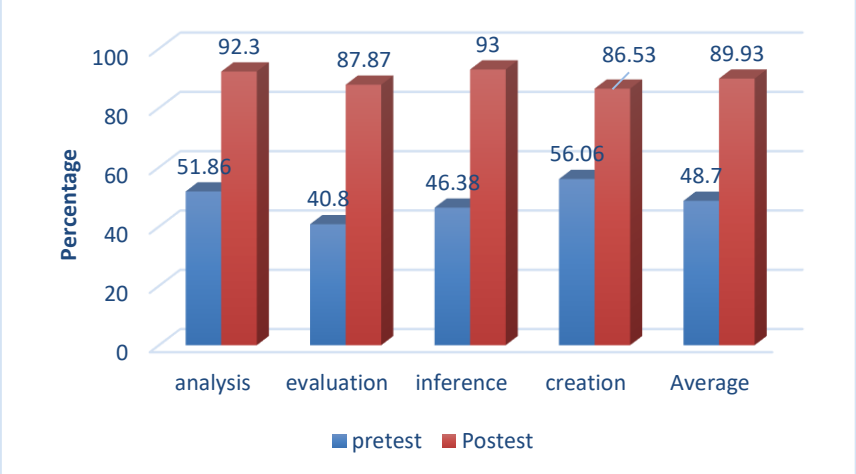


Figure 4. pretest-posttest results graph

Based on the data in Figure 4, it can be concluded that.

Analysis

The assessment of analytical skills was based on pretest and posttest questions that asked students to explain how the phenomenon of global warming occurs. In the pretest, students scored 51.86%, indicating a limited initial understanding of the process of global warming, such as the increase in greenhouse gas emissions and the melting of polar ice caps. After project-based learning, the posttest score increased to 92.3%, reflecting an improvement of 40.44%. This increase suggests that students developed a deeper conceptual understanding of global warming through the learning process, which included problem identification, evaluation of causes, and analysis of the impacts of various factors.

Evaluation

The evaluation indicator involves students' ability to assess and evaluate the causes and effects of global warming. This assessment was conducted through pretest and posttest questions, asking students to evaluate factors such as the contribution of greenhouse gas emissions, deforestation, and other human activities to climate change.In the pretest, students scored 40.8%, indicating that their initial understanding of the causes and effects of global warming was still limited. However, after participating in in-depth project-based learning, their posttest scores significantly increased to 87.87%, reflecting an improvement of 47.07%.

Inference

This inference indicator measures students' ability to draw conclusions based on existing data and information regarding global warming. The pretest and posttest questions assess how well students can make logical conclusions related to the causes of global warming and connect the visual data presented with theoretical concepts about the issue. The pretest results indicate that students scored 46.38%, which suggests that their initial ability to draw accurate conclusions from the provided information is still low. However, after implementing project-based learning that encourages data analysis and inference-making, the posttest score increased to 93%. This improvement of 46.62% demonstrates that students were able to connect visual representations with scientific understanding of the global warming phenomenon and draw more accurate conclusions from the available data.

Creation

This creation indicator assesses students' ability to generate innovative ideas or solutions to address issues related to global warming. The pretest and posttest questions are used to measure how well students can design creative strategies or solutions to mitigate the negative impacts of global warming. In the pretest, students scored 56.0%, indicating that their initial abilities were still low. However, after implementing project-based learning, the posttest score increased to 86.53, reflecting an improvement of 30.53%. This increase signifies a significant advancement in students' ability to create relevant and effective solutions to the issue of global warming.

Normality Test

The pretest and posttest data of the students were analyzed using the Shapiro-Wilk normality test, a method generally recommended for samples with fewer than fifty participants to yield more accurate results (Oktaviani & Notobroto, 2014). Data testing was conducted using SPSS 26.0 for Windows, resulting in a significance value for the pretest of 0.129 > 0.05 and for the posttest of 0.083 > 0.05. This indicates that both data sets have a normal distribution. The results of the normality test are presented in Table 8.

Table 8. Tests of Normality

Tests of normality						
Kolmogorov-Smirnova				Shapiro-Wilk		
	Statistik	Df	Sig.	Statistik	Df	Sig.
Pretest score	1.51	33	.949	.949	33	.129
Postest score	.165	33	.943	.943	33	.083

Homogeneity Test

The homogeneity of the data was assessed using an F-test with the assistance of SPSS 26.0 for Windows, as shown in Table 9. The data in that attachment indicate a significance value of 0.310 < 0.05, which suggests that the data produced is homogeneous and concludes that there is a significant difference between the data groups.

Table 9. Homogeneity Test

ANOVA					
Dependent variabel: pretest score Predictors: (Constant): Postest score					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	3041.432	13	233.956	1.270	.315
Within Groups	3500.083	19	184.215		
Total	6541.515	32			

T-Test

The analysis of the pretest and posttest data using a t-test is presented in Table 10. The calculations indicate a significance value of 0.000 < 0.05. Based on this data, it can be concluded that the null hypothesis (H0) is rejected and the alternative hypothesis (Ha) is accepted, indicating that there is an effect of the PjBL model.

Table 10. T-test Paired Samples

	Mean	SD	SE Mean	Lower	Upper	t	df	Sig
pretest-postest	-41.64	14.93	2.6	-46.93	-36.34	-16.02	32	.00

N-gain value

The results of the n-gain between the pretest and posttest are presented in Table 11. The data show an n-gain value of 0.78, indicating that the PjBL model has a significant effect on students' critical thinking skills, with a level of improvement categorized as high.

Table 11. N-gain score results

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
N-gain	33	.49	1.00	.7848	.13760
N-gain2	33	48.89	100.00	78.4807	13.75988
Valid N (listwise)	33				

Results from applying the PjBL model

The stages of the PjBL learning model in this study consist of: determining fundamental questions, planning the project, scheduling the project creation, monitoring the project, assessing the project results, and evaluation (Herlina, 2021). These stages are outlined as follows:

Determining Fundamental Questions

In the project-based learning (PjBL) approach, the first stage focuses on establishing fundamental questions related to global warming. The teacher actively engages students in identifying and understanding this issue through a series of questions that stimulate critical thinking and deepen students' understanding. This stage aims to ensure that students have a solid foundation in understanding the issue of global warming before they plan and implement the project. Evaluation results show that Groups 1 to 5 scored 100, while Group 6 scored 75. This indicates how students' engagement with fundamental questions can impact the quality of project planning.

Planning the Project

In this stage, students are encouraged to work together in planning a project with a primary focus on the topic of global warming. This planning process involves searching for relevant literature through books and the internet so that students can gather accurate information on the issue. At this stage, groups 1, 2, 3, 4, and 5 each achieved a perfect score of 100. This score indicates the students' ability in these groups to plan the project very well. This suggests that most students followed all instructions carefully, divided tasks effectively, and demonstrated a strong understanding of the global warming material. Conversely, Group scored 75, which is lower compared to the other groups. This score indicates that some aspects of their project planning were less satisfactory or did not meet the excpected standards

Scheduling the project creation

At this stage, each group demonstrates their ability to create a schedule and allocate time for each step in the project creation process. Student activities in this syntax show that Groups 1, 2, 3, 4, 5, and 6 have already been able to plan the project creation well.

Monitoring project creation

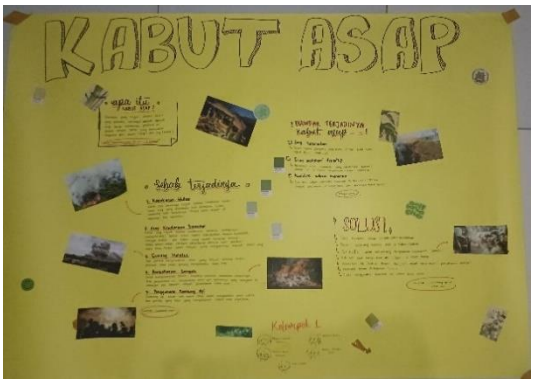
This activity aims to evaluate and ensure that each stage of project creation runs according to the predetermined plan. This process involves ongoing monitoring of various aspects of the project, reporting progress, and identifying and overcoming obstacles that may arise. The following are conclusions regarding group activities based on monitoring results. Group 5 Most Active shows very high activity in every stage of project creation. They are consistent in completing assignments on time, actively participate in discussions, and demonstrate strong collaboration skills. The best practices carried out by this group can be used as an example for other groups. Groups 1 and 2: The Best Groups They were able to complete tasks well and collaborate effectively. Group 3 The Best Group Next is group 6 the less active group.

Testing Project Results

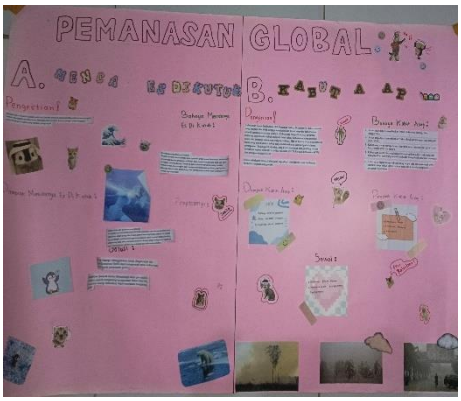
At the stage of testing project results, students present their global warming projects in front of the class. The assessment involves several aspects of critical thinking skills, including a deep understanding of the topic, the ability to respond to questions or criticism with strong reasoning, and the ability to convey information clearly. The presentations showed variation in the groups' abilities to deliver their projects. Group 5 received the highest score of 75, indicating better ability to convey information clearly and engagingly. Meanwhile, Groups 1, 3, 4, and 6 scored 50, indicating that they have the potential to improve the quality of their presentations by improving structure, clarity, and delivery methods.

Project Evaluation

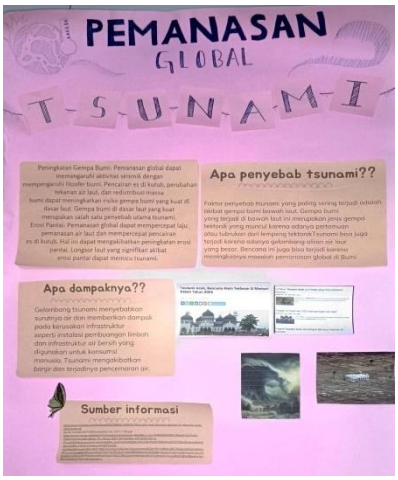
Evaluation is conducted after the entire learning process is completed. This syntax aims to measure the ability to achieve learning objectives through the projects they have worked on. The assessment focuses on various aspects, including the project's relevance to the topic of global warming, the accuracy of the data used, the students' ability to explain and present the project results effectively, and the timeliness of project submission. The form of projects produced by each group is displayed in Figure 5.



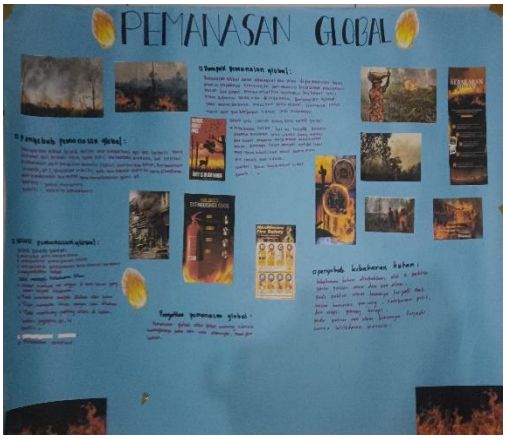
Group 1



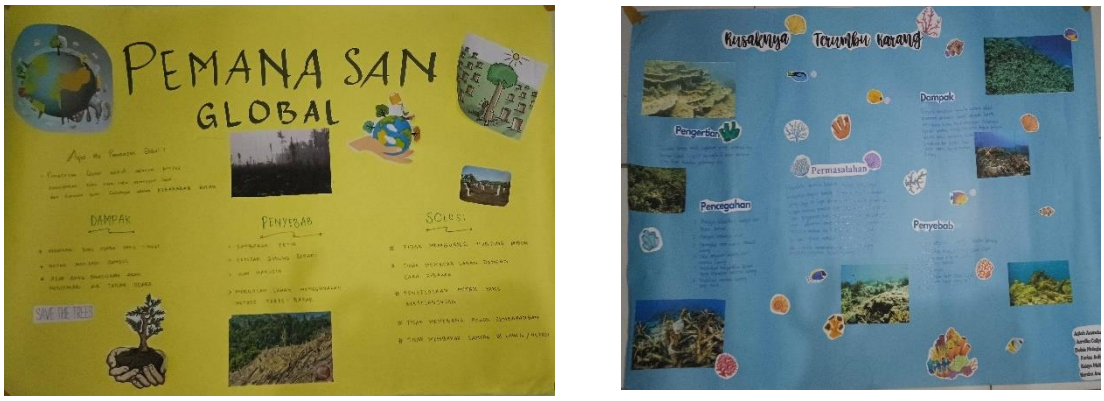
Group 2



Group 3



Group 4



Group 5 Group 6

Figure 5. Student project results

Based on the image shown (Group 1) created a project investigating the issue of haze in the context of global warming. They examined the causes of haze, its impact on the environment and human health, and strategies to mitigate the effects of this phenomenon. (Group 2) chose to delve into the issue of polar ice melting as part of the impacts of global warming. They investigated the factors causing polar ice melting, including the increase in global temperatures leading to ice melt conditions at the poles and the overall rate of global warming. Additionally, this group also considered the haze phenomenon as another impact of global warming. (Group 3) opted to study tsunamis in the context of climate change and global warming. They explored the causes of tsunamis, their environmental impact, and mitigation efforts to reduce tsunami risks. (Group 4) focused on the issue of forest fires as one of the impacts of global warming. They conducted an in-depth analysis of the factors that trigger forest fires, such as hotter and drier weather conditions that increase the risk of fires. This group considered the impact of forest fires and investigated various prevention and mitigation strategies that can be implemented to reduce their negative effects. (Group 5) chose to research the impacts of global warming with a primary focus on deforestation. They identified how deforestation contributes to climate change, reduces biodiversity, and affects the water cycle. Additionally, this group proposed solutions for preserving and restoring forests as steps to mitigate the negative impacts of global warming. (Group 6) analyzed coral reef damage as a result of global warming. They discussed how increasing sea temperatures and ocean acidification impact coral reefs, as well as the importance of coral reefs for marine ecosystems and local economies. The overall average score of the students' projects is displayed in Figure 9.

Table 9. Students' project scores by group

Aspects	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Planning	100	100	100	100	100	100
Implementation	100	100	100	100	100	75
Presentation	50	50	50	75	75	50
Collecting Project results	100	100	75	100	100	100
Average	87,5	87,5	81,25	93,75	93,75	81,25

The data in Table 9 shows the comparison of scores between one group and another. Group 5 demonstrated the best performance with the highest average score of 93.75, followed by Groups

1, 2, and 4 with average scores of 87.5 each, and Groups 3 and 6 with an average of 81.25. Overall, the performance displayed by each group reflects different levels of understanding and application of the material, as well as their ability to collaborate and complete the project. Based on the data obtained, it can be concluded that all groups were able to plan the project, as evidenced by a perfect score of 100 in the planning aspect. The project implementation also showed perfect scores, with all groups receiving a score of 100 in this process. Presentation was the weakest aspect across all groups, except for Group 5, which demonstrated better performance. The presentation aspect was the weakest for almost all groups, except for Group 5, which achieved a higher score of 75. This weakness was caused by a lack of preparation and practice before the presentation, making it difficult for students to convey information in a structured manner. The final results of Groups 1, 2, 4, 5, and 6 received perfect scores of 100, while Group 3 received a score of 75.

DISCUSSION

According to the data analysis, it is clear that the Project-Based Learning (PjBL) model consistently enhances critical thinking skills among students. Previous studies, such as those undertaken by (Ambar et al., 2022; Herlina, 2021; Sumarna & Rushiana, 2023; Zahroh, 2020), have shown an increase in critical thinking skills when students engage in project-based learning activities. These findings align with those studies, indicating that students involved within the PjBL model exhibit significant progress in critical thinking skills. These aspects include the ability to give basic explanations, Develop fundamental abilities, draw conclusions, Provide additional clarifications, and Formulate plans and methods (Khasani et al., 2019). PjBL Stimulates students to actively engage and collaborate, which stimulates the of problem-solving. This process involves students in real-world problems, such as global warming, which require deep analysis, evidence evaluation, and the synthesis of knowledge from various sources. Moreover, the nature of project activities, which encompass planning, execution, and presentation of results, provides repeated opportunities for students to hone their thinking and reasoning skills. These findings suggest that PjBL comprehensively prepares students for future challenges (Junirianto et al., 2023). The implementation of PjBL in the classroom has the advantage of enhancing students' understanding and creativity through project execution (Cahyaningsih et al., 2020). Project-based learning makes students more active in learning (Setyowati & Mawardi, 2018). The PjBL model is a holistic educational approach that engages pupils in collaborative and ongoing investigative tasks. (Desnylasari et al., 2016). Implementation of this model can enhance student engagement and academic achievement (Sitaresmi et al., 2017).

Moreover, this research emphasizes the importance of integrating active learning strategies into the curriculum to develop essential 21st-century skills (Selasmawati & Lidyasari, 2023). By providing concrete evidence of the benefits of PjBL, this research supports educators and policymakers in making informed decisions about educational practices. However, despite the positive results, there are several limitations to acknowledge. First, this study was conducted in only one high school. Second, the duration of PjBL implementation may have been limited, so the long-term effects of PjBL on students' critical thinking skills remain uncertain. Third, the assessment of critical thinking skills may be influenced by observer subjectivity, although efforts have been made to use valid and reliable assessment instruments. Further research with larger samples and various contexts is needed to confirm these findings.

CONCLUSION

Based on the data analysis and discussions conducted, the researcher concludes that the implementation of the Project Based Learning model in the context of global warming has a significant impact on students' critical thinking skills. From this research, there are several findings

that can serve as recommendations. The researcher hopes that other researchers will continue studies with different materials using the Project Based Learning model. Additionally, since the presentation aspect has been identified as a weakness in this study, it is recommended to provide additional training to students to enhance their communication and presentation skills.

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