JPPIPA 12(4) (2026)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Application of the Project Based Learning (PjBL) Model on the Concept of Global Warming to Improve Students' Knowledge of State Senior High School 1 Bandar Bener Meriah

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Received: February 22, 2026
Revised: March 13, 2026
Accepted: April 25, 2026
Published: April 30, 2026

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DOI: 10.29303/jppipa.v12i4.14654

Abstract: Project Based Learning (PjBL) is a learning model that emphasizes active student involvement in the learning process through contextual and meaningful project activities. This study aims to analyze the application of the Project Based Learning (PjBL) model to the concept of global warming and its impact on the knowledge of tenth-grade students. This study used a quantitative approach with a quasi-experimental method and a pretest–posttest control group design. The research sample consisted of two classes: class IA X-1 with 22 students as the experimental class and class IA X-2 with 21 students as the control class, resulting in a total sample of 43 students. The experimental class was given treatment in the form of learning using the PjBL model, while the control class used conventional learning. The research instrument was a knowledge test administered before and after the treatment. Data were analyzed using descriptive statistics and N-Gain calculations. The results showed that there was a difference in knowledge gain between the experimental and control classes. The increase in student knowledge in the experimental class was higher than in the control class, with the N-Gain results being in the moderate to high category. Based on these results, it can be concluded that the implementation of the Project Based Learning (PjBL) model is effective in increasing student knowledge on the concept of global warming.

Keywords: Biology learning; Global warming; Project based learning; Student knowledge

Introduction

Global warming is a global environmental issue that has garnered global attention due to its far-reaching impact on life on Earth. The increase in the Earth's average surface temperature is caused by increasing concentrations of greenhouse gases in the atmosphere, largely from human activities such as the use of fossil fuels, land conversion, and industrial activity. This condition triggers various environmental changes, including ecosystem imbalances, environmental degradation, and increased disaster risks due to climate change. Therefore, an understanding of global warming needs to be instilled from an early age through formal education.

In biology lessons at the high school level, global warming material is closely related to everyday life and environmental phenomena surrounding students. However, the learning process in schools still tends to use a conventional, teacher-centered approach. The lecture-dominated learning method discourages students from actively participating and hinders their ability to connect learned concepts to real-life environmental problems. As a result, students'

How to Cite:
Murni, D., Jailani, Akmal, N., Apriana, E., & Fakhrurrazi. (2026). Application of the Project Based Learning (PjBL) Model on the Concept of Global Warming to Improve Students' Knowledge of State Senior High School 1 Bandar Bener Meriah. *Jurnal Penelitian Pendidikan IPA*, *12*(4), 533–538. https://doi.org/10.29303/jppipa.v12i4.14654

conceptual understanding remains relatively low, and learning outcomes are less than optimal.

This issue highlights the importance of implementing learning models that encourage active student involvement in the learning process. One alternative learning model deemed appropriate is Project-Based Learning (PjBL). This model positions students as the subjects of learning through project activities that require them to conduct investigations, collaborate, and produce products as a means of understanding the material being studied. Thus, Project-Based Learning (PjBL) enables students to construct knowledge independently through meaningful learning experiences.

Numerous studies have shown that the application of Project-Based Learning (PjBL) in science learning can improve students' conceptual understanding, learning motivation, and critical thinking skills. In the case of global warming, project-based learning can connect theoretical concepts with real-world environmental conditions, enabling students to more easily understand the causes, impacts, and mitigation efforts. This contextual learning process also encourages students to be more environmentally conscious.

Based on this description, this study aims to analyze the application of the Project-Based Learning (PjBL) model to the concept of global warming and its impact on improving student knowledge. The results of this study are expected to serve as a reference in developing innovative biology learning that is oriented towards improving the quality of learning in schools.

Method

This study employed a quantitative approach with an experimental design to examine the effect of treatment under controlled conditions. The research utilized a pretest–posttest control group design involving two groups, namely an experimental class and a control class, both of which were administered a pretest and a posttest. The experimental class received instruction based on naturalistic intelligence through the Project Based Learning (PjBL) model, while the control class was taught using conventional learning methods.

The study was conducted at SMA Negeri 1 Bandar Bener Meriah during the second semester of the academic year. The population consisted of all tenth-grade science students (Class X IA), with a total sample of 43 students selected through purposive sampling based on comparable initial abilities, comprising 22 students in the experimental class and 21 students in the control class. Data collection techniques included observation to assess students' responses to the learning process, a test consisting of 25 multiple-choice items administered as pretest and posttest to measure critical thinking skills, and questionnaires to obtain supporting data. Data analysis was carried out by calculating the gain score and normalized gain (N-gain) to determine the improvement in learning outcomes, which were classified into high, medium, and low categories. Hypothesis testing was conducted using an independent samples t-test at a specified level of significance to determine differences in mean learning outcomes between the experimental and control groups.

Figure 1. Pretest-posttest control group design

Result and Discussion

The research subjects consisted of two classes: an experimental class with 21 students and a control class with 22 students. The research data were obtained through knowledge tests in the form of pretests and posttests, then analyzed to determine the gain and N-gain as indicators of student knowledge improvement.

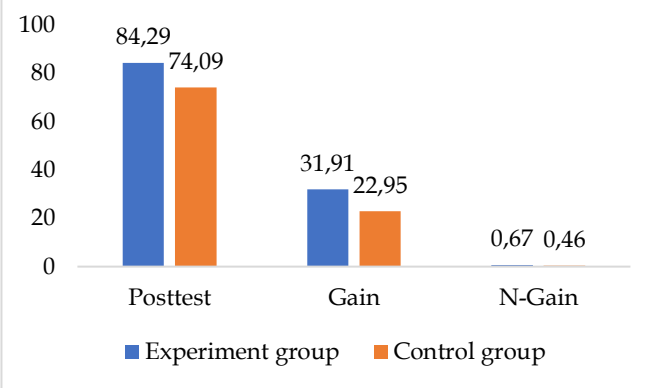

Figure 2. Comparison of posttest, gain, and N-gain

Student Pretest Result

A pretest is given before treatment to determine students' initial abilities. In the experimental class, consisting of 21 students, the average score was 52.38. The range of scores in this class was at a minimum of 40 and a maximum of 65. On the other hand, the control class, with 22 students, showed results that were not

much different, namely an average score of 51.14 with a range of scores between 38 and 63.

Table 1. Pretest Results of the Experimental and Control Classes

Class	Number of Students	Minimum Score	Maximum Score	Mean Score
Experimental	21	40	65	52.38
Control	22	38	63	51.14

Posttest Results, Gain, and N-Gain of Students

After the learning process was completed, students in the experimental class were taught using the Project-Based Learning (PjBL) model, while the control class used conventional learning. A posttest was then administered to determine student knowledge gains.

Based on the data presented in Table 2, there was a significant difference in learning outcomes between the experimental and control classes after the treatment. The following is a narrative analysis of the posttest results, score (Gain), and effectiveness of the improvement (N-Gain) for both classes.

Table 2. Posttest Results, Gain, and N-Gain

Class	Mean Pretest	Mean Posttest	Gain	N-Gain	Category
Experimental	52.38	84.29	31.91	0.67	Moderate–High
Control	51.14	74.09	22.95	0.46	Moderate

Notes: Gain = Posttest score – Pretest score; N-Gain = (Posttest – Pretest) / (100 – Pretest)

After the learning process was completed, both classes showed an increase in average scores. However, the experimental class achieved a significantly higher achievement with an average of 84.29, while the control class achieved an average of 74.09. This 10.20-point difference in posttest scores indicates that the method or treatment applied to the experimental class was more effective in helping students understand the material compared to the conventional method used in the control class.

Interpretation of Effectiveness through N-Gain

To more accurately and objectively assess the effectiveness of the treatment, the N-Gain (Normalized Gain) score is used. The N-Gain score normalizes score improvement by taking into account the maximum potential students can achieve. (a) The Experimental Class achieved an N-Gain score of 0.67, which is in the Moderate to High category. This figure indicates that the experimental class successfully achieved 67% of the total potential score improvement. (b) The Control Class achieved an N-Gain score of 0.46, which is in the Moderate category.

This N-Gain difference of 0.21 provides strong evidence that the use of the learning model in the experimental class had a more significant positive impact.

Description of Results

Based on Table 2, it can be observed that: (1) The mean posttest score of the experimental class is higher than that of the control class, indicating that the implementation of the Project Based Learning (PjBL) model had a positive impact on students' learning outcomes. (2) The gain score of the experimental class is greater than that of the control class, demonstrating a higher improvement in students' knowledge in the experimental group. (3) The N-gain value of the experimental class falls into the moderate–high category, whereas the control class is categorized as moderate.

Statistical Test Results

Normality Test

The normality test was conducted to determine whether the data were normally distributed. All significance values are greater than 0.05, indicating that the data are normally distributed.

Table 3. Normality Test Results

Class	Sig. Pretest	Sig. Posttest	Description
Experimental	0.200	0.173	Normal
Control	0.186	0.158	Normal

Homogeneity Test

The homogeneity test results indicate that the variances of both classes are homogeneous.

Table 4. Homogeneity test results

Data	Sig.	Description
Posttest	0.412	Homogeneous

Hypothesis Testing (t-test)

The significance value is less than 0.05, indicating a statistically significant difference between the learning outcomes of students in the experimental class and those in the control class.

Table 5. Posttest t-test results

Data	Sig. (2-tailed)	Decision
Posttest	0.001	H_0 Rejected

Discussion

The results of the study showed that the application of the Project-Based Learning (PjBL) model to the concept of global warming significantly improved students' knowledge. This was demonstrated by the higher average posttest, gain, and N-gain scores of the experimental class compared to the control class.

The implementation of the Project-Based Learning (PjBL) model in the concept of global warming has been shown to have a positive impact on improving students' knowledge, particularly in terms of conceptual understanding and scientific literacy. This is consistent with the characteristics of PjBL, which emphasize experiential learning and active student engagement in solving contextual problems (Bell, 2010; Kokotsaki et al., 2016; Susilawati et al., 2025). In science education, this approach is considered effective in integrating theoretical concepts with real-world phenomena, thereby making learning more meaningful (Huffman et al., 2016; Susilawati et al., 2023).

In the context of global warming, PjBL provides opportunities for students to explore climate change issues through project activities such as greenhouse effect experiments, environmental data analysis, and environmental awareness campaigns. These activities have been proven to enhance students' conceptual understanding as they are directly involved in the knowledge construction process (Asidiq et al., 2025; Krisdiana et al., 2023). Furthermore, project-based learning increases students' learning motivation by allowing space for creativity and independence (Chiang et al., 2016).

Research findings indicate that the application of PjBL in global warming topics significantly improves students' learning outcomes, both in cognitive aspects and science process skills. Students who learn through PjBL demonstrate higher achievement compared to those taught using conventional methods (Hafitri et al., 2024; Indrawati, 2019). In several studies, this improvement is also accompanied by students' enhanced ability to interpret data and draw accurate scientific conclusions (Han et al., 2016).

In addition to improving conceptual understanding, PjBL also contributes to the development of students' scientific literacy, particularly in understanding global issues such as climate change. Scientific literacy is crucial because students are not only expected to understand concepts but also to make evidence-based decisions (Astuti, 2020; Nugroho et al., 2025). In this regard, project-based learning enables students to relate global warming concepts to real-life situations, thereby increasing the relevance of learning (Holm, 2018).

Furthermore, the implementation of PjBL has been shown to enhance students' critical thinking and problem-solving skills. Through investigation and group discussions, students are trained to analyze environmental problems and formulate appropriate solutions (Rahmawati, 2022; Wurdinger et al., 2016). This is highly relevant to the demands of 21st-century education, which emphasize higher-order thinking skills.

Student engagement is a key factor in the success of PjBL, especially in global warming learning. Studies show that student participation in project-based learning increases significantly, which in turn leads to a more comprehensive understanding of concepts (Sari, 2021; Sumilat et al., 2025). This engagement fosters deeper learning compared to traditional instructional methods.

The integration of technology in PjBL also contributes positively to learning effectiveness. The use of digital media and online platforms allows students to access broader information and present their project outcomes more attractively (Butsriruk et al., 2023; Yani, 2025). Consequently, learning becomes more interactive and adaptable to technological advancements.

However, the implementation of PjBL is not without challenges. One of the main limitations is the longer time required compared to conventional teaching methods, as well as the need for teachers' readiness in designing and managing project-based activities (Kokotsaki et al., 2016; Peny et al., 2022). Additionally, differences in students' abilities to work independently and collaboratively may affect the effectiveness of project-based learning (Huffman et al., 2016).

Despite these challenges, overall, PjBL is an effective learning model for improving students' knowledge in the concept of global warming. This model not only focuses on cognitive aspects but also develops critical thinking skills, collaboration, and environmental awareness. Therefore, PjBL can be considered a relevant instructional approach for addressing the challenges of 21st-century education, particularly in fostering a generation that is more aware of global climate change issues (Aswiroh et al., 2025; Nugroho et al., 2025).

Conclusion

Based on the research results and discussion, it can be concluded that: The implementation of the Project-Based Learning (PjBL) model has been proven to have a positive and significant impact on increasing students'

knowledge of the concept of global warming. This is demonstrated by the higher average post-test scores of the experimental class compared to the control class, namely 84.29 in the experimental class and 74.09 in the control class; The increase in students' knowledge in the experimental class was greater than in the control class, as indicated by the gain and N-gain values. The experimental class obtained an N-gain value of 0.67, categorized as medium-high, while the control class obtained an N-gain value of 0.46, categorized as medium. This difference indicates that learning using the PjBL model is more effective than conventional learning; The results of the statistical test using the t-test showed a significance value of 0.001 (<0.05), therefore the null hypothesis (H_0) was rejected. Thus, it can be concluded that there is a significant difference between the knowledge of students learning using the Project-Based Learning model and students learning using conventional learning; The Project-Based Learning model can increase students' active involvement in the learning process through project activities that require students to observe, analyze, discuss, and present project results. This contextual, student-centered learning process encourages a more meaningful understanding of the concept of global warming.

Acknowledgments
All author would like to thank to all parties who has supported this research.

Author Contributions
Conceptualization, formal analysis, writing—original draft preparation, project administration, methodology, software, data curation, D.M. and J.; validation, investigation, resources, supervision, writing—review and editing, visualization, N.A., E.A., and F. All authors have read and agreed to the published version of the manuscript.

Funding
This research received no external funding.

Conflicts of Interest
This research has no conflicts of interest.

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