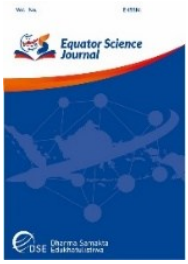
EQUATOR SCIENCE JOURNAL (ESJ)
e-ISSN: 2988-3881
Journal homepage:
https://ejournal.edukhatulistiwa.com/index.php/ESJ



Implementation of STEM-Based Learning through Greenhouse Effect Experiments to Improve Students' Understanding of the Global Warming Concept

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Received: January 26, 2026. Revised: February 6, 2026. Accepted: February 25, 2026.
First Available Online: February 27, 2026. Publication Date: February 28, 2026.
DOI: 10.61142/esj.v4i1.330

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Keywords *:*
STEM Learning,
Global Warming,
Conceptual Understanding

ABSTRACT
Global warming is an important global environmental issue for students to understand since junior high school (SMP) level. However, students' conceptual understanding of this material is still relatively low because it is abstract and often presented theoretically. This study aims to determine the improvement in junior high school students' understanding of the concept of global warming through the implementation of STEM-based learning using greenhouse effect experiments. This study used a quantitative approach with a quasi-experimental design of one-group pretest–posttest type. The subjects were 11 eighth-grade junior high school students. The research instruments were conceptual understanding tests given before (pretest) and after (posttest) the treatment, as well as observation sheets for the implementation of learning. Data were analyzed using descriptive statistics and N-Gain calculations. The results showed that the average posttest score (62.73) was higher than the average pretest score (54.55). However, the N-Gain calculation result of 0.18 is in the low category. This finding indicates that the implementation of STEM-based learning through the greenhouse effect experiment can improve students' understanding of the concept of global warming, although the improvement obtained is still

relatively low. Therefore, STEM-based learning needs to be implemented sustainably and combined with other learning media to increase the effectiveness of students' conceptual understanding.

INTRODUCTION

Global warming, defined as the increase in the Earth's average atmospheric, oceanic, and land surface temperatures due to rising greenhouse gas concentrations, is a critical environmental issue that must be understood from an early stage of education. At the junior high school level, students' understanding of global warming concepts remains limited, as learning activities are often dominated by theoretical explanations with minimal connection to real-world phenomena (Plutzer et al., 2024). As a result, students frequently struggle to construct meaningful conceptual understanding of abstract climate-related processes.

This condition is also evident in science learning at MTs Al-Maarif, Sorong Regency, Papua, a region that has received relatively little attention in empirical research on STEM-based science education. Most previous studies on STEM learning and global warming have been conducted in urban or well-resourced schools, while research in eastern Indonesian contexts, particularly Papua, remains scarce. Differences in geographical conditions, educational access, and learning resources indicate the need for context-specific instructional approaches that are suitable for schools in this region.

In addition, limited laboratory facilities and instructional media in many junior high schools in Sorong pose challenges for implementing complex or technology-intensive experiments. These constraints necessitate the use of simple, low-cost experimental designs that are feasible within the school environment while still enabling students to engage in meaningful scientific inquiry. A simple greenhouse effect experiment using readily available materials offers a practical alternative for illustrating the mechanism of heat trapping in the Earth's atmosphere.

Unlike many previous studies that emphasize students' attitudes, creativity, or scientific literacy, this study specifically focuses on students' conceptual understanding of global warming. Conceptual understanding is a fundamental cognitive outcome in science learning, as it reflects students' ability to comprehend, explain, and apply scientific concepts rather than merely recalling factual information. Therefore, this study addresses an important research gap by examining how STEM-based learning through a simple greenhouse effect experiment can support the development of conceptual understanding among junior high school students in a resource-limited context (Novia et al., 2025).

The urgency of using innovative learning approaches such as STEM (Science, Technology, Engineering, and Mathematics)–based learning is increasing in line with the demands of 21st-century education, which emphasizes critical thinking, creativity, and authentic problem-solving skills (Abanoz & Yabaş, 2025). STEM-based learning enables students to integrate knowledge from multiple disciplines to understand real-world phenomena in a more meaningful way.

Previous studies have reported positive contributions of STEM-based learning in science education. For example, the use of STEM-based student worksheets (LKPD) on global warming material has been shown to support the development of students' scientific attitudes and learning engagement (Apriliana et al., 2025). Similarly, the implementation of the STEM-6E learning model has been reported to encourage students' creative thinking in global warming instruction (Na'ilufari et al., 2024). However, these studies primarily focused on affective outcomes or higher-order thinking skills rather than on students' conceptual understanding.

Furthermore, experiments are an important component of STEM learning because they provide hands-on experiences that reinforce understanding of scientific concepts. The use of greenhouse effect prototypes in STEM-based learning contexts has been reported to support students' problem-solving abilities related to climate phenomena (Leksono et al., 2025; Maharani et al., 2025). Practical activities allow abstract concepts such as global warming to become more tangible and accessible for students (Mangasi et al., 2024).

Based on this background, this study applies a STEM-based learning approach through a greenhouse effect experiment to support students' understanding of the concept of global warming at

MTs Al-Maarif, Sorong Regency. The experiment is designed to engage students through observation, experimentation, and reflection, enabling the development of conceptual understanding and science process skills within existing school constraints (Aeschbach et al., 2025).

The purpose of this study is to examine the extent to which STEM-based learning through a greenhouse effect experiment can contribute to changes in students' conceptual understanding of global warming and to describe student engagement during the learning process. Accordingly, the hypothesis of this study is that the application of STEM-based learning through a greenhouse effect experiment can support improvements in students' conceptual understanding of global warming compared to conventional learning.

METHOD

Research Design

This study employed a quantitative approach with a quasi-experimental one-group pretest–posttest design (Ramadita et al., 2021; Ifah et al., 2025). This design was chosen to examine the effect of implementing STEM-based learning through experiments on the greenhouse effect on MTs students' understanding of the concept of global warming. In this design, students were given a pretest before the treatment and a posttest after the treatment.

Schematically, the research design can be depicted as follows:

$$\mathbf{O_1 - X - O_2}$$

Description:

$\mathbf{O_1}$ = pretest, **X** = STEM-based learning treatment, and $\mathbf{O_2}$ = posttest.

The subjects of this study were seventh-grade students of MTs Al-Maarif, Sorong Regency, studying global warming and climate change. The sample size was 11 students. The sampling technique used was purposive sampling, considering that the selected classes had received supporting materials related to the environment and had relatively homogeneous academic characteristics (Ramadita et al., 2021). All students in the selected class participated in the study. Therefore, the findings should be interpreted cautiously and cannot be generalized beyond the context of this study.

Research Instrument

The materials and instruments used in this research include (Putri & Muttaqiin, 2022): (a) Learning Materials: The learning materials consist of STEM-based science learning modules and Student Worksheets (LKPD) designed to support the implementation of the greenhouse effect experiment; (b) Experimental Tools and Materials: The experimental tools and materials consist of two transparent glass jars, clear plastic, rubber bands, a digital thermometer, a light source (sun or lamp), and a temperature observation sheet; (c) Conceptual Understanding Test Instrument: The test instrument consists of pre- and post-test questions designed to measure understanding of the concept of global warming; (d) Documentation: Documentation in the form of photographs and field notes was used as supporting data.

The research procedure was carried out through the following stages (Sinambela & Sipahutar, 2025): (a) Preparation Stage, researchers prepared learning materials, test instruments, and observation sheets. Next, coordination was conducted with the school and science teachers regarding the research implementation; (b) Implementation Stage, students were given a pretest to determine their initial understanding of the concept of global warming and STEM-based learning. After completing the entire learning series, students were given a posttest to measure their final conceptual understanding; (c) Data Collection Stage, research data was obtained from the results of the pretest and posttest, as well as activity documentation.

The conceptual understanding test data were analyzed quantitatively using descriptive and inferential statistics (Sugiono, 2013). The analysis included calculating the mean, maximum, and minimum scores, and measuring the improvement in students' conceptual understanding using N-Gain . To determine significant differences between pretest and posttest scores, a paired sample t-test was

conducted with a significance level of 0.05. Data analysis was performed using SPSS software and Microsoft Excel for initial data processing and graphic visualization.

RESULTS AND DISCUSSIONS

The results of the observation of the implementation of learning indicate that the application of STEM-based learning through the greenhouse effect experiment can be carried out well according to the plan. All stages of learning, starting from problem orientation, experimental design, experimental implementation, data analysis, and reflection, were carried out systematically. Students demonstrated active involvement throughout the learning process. During the experimental design and implementation stages, students were able to work together in groups to prepare tools and materials, take temperature measurements, and record observation data. These activities indicate that the targets of STEM-based learning activities were achieved, especially in the aspects of collaboration, problem-solving, and science process skills (Simanjuntak & Purwaningsih, 2020).

The main product of this lesson is a simple greenhouse effect experiment model using two transparent glass jars, clear plastic, and a digital thermometer. This model is designed to simulate the mechanism of heat trapping in the Earth's atmosphere (Leksono et al., 2025). Experimental product specifications: (a) Main media: two transparent glass jars; (b) Treatment: open jar and jar covered with clear plastic, (c) Measuring instrument: digital thermometer, (d) Observation time: 0 minutes and 30 minutes. Product advantages: (a) Uses simple and readily available tools and materials; (b) Safe for use by junior high school students; (c) Enables concrete visualization of the abstract concept of the greenhouse effect; (d) Supports the integration of Science, Technology, Engineering, and Mathematics.

The temperature measurements showed a difference in temperature increase between the open jar and the clear plastic-covered jar. The closed jar experienced a higher temperature increase than the open jar at each observation time interval (Gahansa et al., 2025).

Tabel 1. Comparison of Temperature Increase in Open and Closed Jars

Group	Time (minute)	Open Jar Temperature (ºC)	Closed Jar Temperature (ºC)
1	0	27	27ºC
	30	32	31
2	0	27	27
	30	31	30
3	0	28	28
	30	30	30
4	0	29	29
	30	33	32

Based on Table 1, it can be seen that the temperature in the plastic-covered jar increased more than in the open jar at each observation time interval. The temperature difference began to appear at minute 0 and continued to increase until minute 30. This indicates that the plastic cover plays a role in retaining heat, preventing incoming heat from easily escaping from the system. These results indicate that the plastic cover functions to retain heat, preventing incoming heat energy from easily escaping. This phenomenon serves as an analogy for the greenhouse effect mechanism in Earth's atmosphere.

Students' conceptual understanding was analyzed through pretest and posttest results. The analysis showed that the average posttest score was higher than the average pretest score. Furthermore, the N-Gain calculation results were in the moderate to high category, indicating an increase in understanding of the concept of global warming after the implementation of STEM-based learning (Masida et al., 2025).

Tabel 2. Comparison of Average Pretest and Posttest Values for Concept Understanding

No	Name	Score	
		Pretest	Postest
1	WA	30	60
2	DD	80	80
3	FA	70	80
4	NN	30	50
5	SN	60	60
6	AA	70	90
7	AN	30	20
8	BM	40	60
9	FZ	70	70
10	AF	70	60
11	JR	50	60
Average		54.55	62.73

Tabel 3. N-Gain Value of Understanding the Concept of Global Warming

Pretest average	Postest average	N-Gain	Category
54.55	62.73	0.179	Rendah

The results in tables 2 and 3 indicate that the research objective of improving junior high school students' understanding of the concept of global warming has not been achieved. Based on the one-group pretest–posttest design used in this study, the analysis of the results focused on comparing students' conceptual understanding before (O_1) and after treatment (X) in the form of STEM-based learning through a greenhouse effect experiment. The results showed that the average posttest score (O_2) was higher than the average pretest score (O_1). This increase indicates a change in students' conceptual understanding after being given STEM-based learning treatment.

Based on the pretest and posttest analysis results, the average posttest score (62.73) was higher than the average pretest score (54.55). However, the N-Gain calculation result of 0.18 is in the low category. This indicates that although there was an increase in understanding of the concept of global warming after the implementation of STEM-based learning, this increase is still relatively low.

In the context of a quasi-experimental one-group pretest–posttest design, the difference in scores between the pretest and posttest indicates a change in students' conceptual understanding after the STEM-based learning treatment. However, the low N-Gain value indicates that the learning effectiveness in improving understanding of the concept of global warming is still limited.

The low N-Gain value can be caused by several factors, including limited learning time, the complexity of the abstract global warming material, and students' limited prior experience with experimental-based learning. Furthermore, the use of a design without a control group also limits the strength of causal inferences regarding learning outcomes.

Nevertheless, these results still demonstrate the potential of STEM-based learning in helping students understand the concept of global warming. This finding aligns with previous research suggesting that STEM learning requires sustained and structured implementation to significantly impact conceptual understanding (Barclay & Bentley, 2021).

CONCLUSION AND SUGGESTION

Based on the research results and discussion, it can be concluded that the application of STEM-based learning through the greenhouse effect experiment in junior high school students can improve the

understanding of the concept of global warming. This is indicated by an increase in the average post-test score compared to the average pre-test score after the implementation of STEM-based learning. However, the results of the N-Gain calculation show a value of 0.18, which falls into the low category. This indicates that the improvement in conceptual understanding remains limited. In the context of a quasi-experimental one-group pretest–posttest design, these findings suggest that STEM-based learning through the greenhouse effect experiment has the potential to support students' understanding of the concept of global warming, but its effectiveness is still constrained by several factors, including learning duration, the complexity of the material, and students' prior experience with experiment-based learning.

Based on the research results obtained, several suggestions can be put forward as follows. First, science teachers are advised to implement STEM-based learning continuously and not limited to a single meeting, so that students have broader opportunities to build conceptual understanding through repeated and in-depth learning experiences. Second, STEM learning on global warming material needs to be combined with other supporting media, such as digital simulations, learning videos, or environmental-based projects, to help students understand abstract concepts. Third, further research is recommended to use an experimental design involving a control group so that the effect of STEM-based learning on conceptual understanding can be analyzed more comprehensively. Fourth, further research can also examine the effect of STEM-based learning on other aspects, such as scientific literacy, environmental awareness, and students' critical thinking skills.

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