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Improving Critical Thinking Skills of High School Students through STEM-Based PBL LKPD on Global Warming Materials

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Abstrak

Keterampilan berpikir kritis siswa di sekolah pada materi pemanasan global belum mengalami peningkatan. Penelitian ini bertujuan untuk menganalisis efektivitas LKPD PBL (sains, teknologi, rekayasa, matematika) berbasis STEM dalam meningkatkan keterampilan berpikir kritis siswa khususnya pada materi pemanasan global. Metode penelitian yang digunakan adalah eksperimen dengan rancangan one-group pretest-posttest design yang melibatkan 36 siswa kelas X SMA Negeri Kesamben Jombang. Hasil penelitian menunjukkan bahwa terdapat peningkatan keterampilan berpikir kritis siswa yang signifikan setelah diterapkan pembelajaran PBL berbasis STEM pada materi pemanasan global. Rata-rata skor pretest sebesar 45,72 meningkat menjadi 79,89 pada posttest dengan rata-rata skor N-Gain sebesar 0,742 yang menunjukkan peningkatan sebesar 74,22% dengan kategori tinggi sebanyak 21 siswa, 11 siswa pada kategori sedang dan 4 siswa pada kategori rendah. Pendekatan STEM diterapkan dalam pembelajaran fisika dengan tujuan tidak hanya untuk meningkatkan keterampilan berpikir kritis tetapi juga membantu siswa dalam mengembangkan keterampilan abad 21.

Kata Kunci: LKPD, PBL-STEM, Keterampilan Berpikir Kritis

Abstract

The critical thinking skills of students in schools on global warming materials have not improved. This study aims to analyze the effectiveness of STEM-based PBL (science, technology, engineering, mathematic) LKPD in improving students' critical thinking skills, especially on global warming materials. The research method used was an experiment with a one-group pretest-posttest design involving 36 students of class X of SMA Negeri Kesamben Jombang. The results of the study showed that there was a significant increase in students' critical thinking skills after implementing STEM-based PBL learning on global warming materials. The average pretest score of 45.72 increased to 79.89 in the posttest with an average N-Gain score of 0.742 which showed an increase of 74.22% with the high category in 21 students, 11 students in the medium category and 4 students in the low category. The STEM approach is implemented in physics learning with the aim of not only improving critical thinking skills but also helping students in developing 21st century skills.

Keywords: *LKPD, PBL-STEM, Critical Thinking Skills*

A. Introduction

Science and technology are developing rapidly and have an impact on all aspects of life and education. Technological developments are a challenge for teachers to prepare students to respond to various changes in the 21st century. Students are required to have 4C (Critical Thinking, Creativity, Collaboration, Communication) skills. One of the skills that must be mastered is critical thinking skills that are not only important but also the main foundation in facing increasingly complex and dynamic global challenges. This ability includes the ability to analyze, evaluate, and solve problems in an effective way is a non-negotiable competency in today's modern era (Pratiwi & Doyan, 2024).

In the current era of digital transformation, the world of education faces fundamental challenges in preparing students to live in a society that is increasingly dependent on science and technology. The acceleration of technological innovation demands that learning no longer focuses merely on the transfer of knowledge but rather on developing students' ability to think critically, creatively, and adaptively. Teachers are required not only to be transmitters of information but also facilitators who can design meaningful learning experiences. According to (Trilling & Fadel, 2009), 21st-century learning emphasizes the need to develop skills that enable learners to solve real-world problems through reasoning, collaboration, and technological literacy. Thus, education must be oriented toward fostering reasoning abilities that encourage students to be critical observers of reality, especially in addressing global issues such as environmental damage and climate change (Dewey, 1933; Fullan & Langworthy, 2014; Schleicher, 2018).

Critical thinking skills can basically be trained through many disciplines, one of which is physics learning. In learning physics in schools, critical thinking skills are important in solving problems (Nurohman et al., 2014). Through concepts in physics, it can be used to train students' critical thinking skills, one of which is on global warming material.Global warming is an increase in the average temperature on earth (Damari, 2022). Based on IPCC data, the increase

in the earth's temperature since 1901 has reached 0.89°C and in the Southeast Asian region, the temperature increase was recorded at around 0.4°C-1°C (Utami, 2020). In Indonesia, the temperature increase reached 0.005°C-1.18°C (Alfiandy et al., 2022). The biggest cause of the increase in average temperature on Earth is human activities that do not pay attention to the balance of nature so that it has an extraordinary impact on all creatures in nature (Azizah et al., 2022; Rahmadania, 2022). Thus, preventive measures are needed through global warming education awareness so that they do not feel its impact in the future.

Learning physics offers a strategic platform to build these competencies because physics concepts are directly related to natural phenomena and problem-solving processes. When students learn about phenomena like heat transfer, energy conservation, and atmospheric changes, they are not only learning abstract theories but also developing analytical skills to understand the causes and effects of global warming. As emphasized by (Lawson, 2002), scientific learning such as physics can strengthen critical thinking because it encourages hypothesis formulation, evidence testing, and logical inference-making. Therefore, integrating critical thinking elements into physics learning on global warming material is not just relevant but necessary to build students' awareness and scientific reasoning about sustainability and environmental responsibility (Bybee, 2013; Driver et al., 1996).

The fact that in schools, the critical thinking skills of students are still relatively low, including global warming materials (Hidayah & Permadi, 2023). The majority of students do not understand education about global warming so that it can threaten the safety of life in the future. In facing this problem, it is important for students to have a deep understanding of the importance of minimizing its causes which is adapted to 21st century learning related to thinking skills, namely the 4Cs. One of them is the ability to think critically, where this ability plays an important role and must be possessed by students (Septikasari, 2018). The ability to think critically is the ability to think logically to determine the truth and find ideas in solving problems as evidenced by various evidences in the form of data or facts (Permana & Chamisijatin, 2019; Windari & Yanti, 2021). With this ability, students are able to take action in overcoming problems that occur in life related to global warming logically and critically argumentation.

Global warming, as one of the most urgent global problems, requires educational interventions that do not merely transfer knowledge but shape awareness and behavioral change. Students need to understand that this issue is not distant but closely related to their daily lives from waste generation and energy consumption to transportation habits. The role of education is to cultivate eco-literacy, which (Capra, 2005) defines as the understanding of the principles of ecological interdependence that sustain life. Through this literacy, students will not only master scientific concepts but also build moral responsibility to act in harmony with nature. Integrating global warming material into physics through a contextual learning model

such as STEM-based Problem Based Learning allows students to connect scientific principles with practical problem-solving and innovation in real life (Frick et al., 2021; Hernández-Barco et al., 2022).

New ideas are needed in the delivery of material from teachers that are in accordance with the selection of learning models, strategies, approaches, and media (Fadhlina & Suriana, 2022). The learning that can be used is the Problem Based Learning (PBL) model. The PBL model is a model that deals with authentic (real) problems and allows students to solve problems from the knowledge they already have to develop critical, creative and good communication thinking from students (Arends, 2014). To make it easier to solve problems, an approach is needed, namely STEM. STEM is an approach in learning in which students can design, develop, and use technology, as well as apply knowledge in problem solving so that they can improve critical thinking skills (Nurazmi & Bancong, 2021). In line with research from (Setiana & Madlazim, 2021; Tahsinia et al., 2023)states that the integrated learning model, especially PBL, affects students' critical thinking skills. Thus, the STEM-based PBL model is very suitable to be applied and can be collaborated in improving critical thinking skills, because it can solve authentic problems including global warming by collaborating the four STEM fields.

The integration of the STEM approach with the PBL model is an educational innovation that aligns with 21st-century competencies. PBL positions students as active learners who explore authentic problems, formulate hypotheses, conduct investigations, and present solutions collaboratively. When combined with STEM, this model connects theory with practical applications in science, technology, engineering, and mathematics, thus strengthening students' analytical and creative thinking. Research by (English & King, 2015) shows that the implementation of STEM-based PBL can enhance students' critical and innovative thinking through project-oriented learning. In the context of global warming, students can, for example, design simple models of renewable energy or create experiments that illustrate greenhouse effects, thereby translating abstract knowledge into meaningful understanding (Bybee, 2013; Freeman et al., 2014; Honey et al., 2014).

Nevertheless, transforming learning practices in schools still faces systemic barriers. Many teachers are accustomed to conventional approaches such as lectures and direct instruction that prioritize the completion of curriculum content over the cultivation of thinking skills. This situation leads to the dominance of teacher-centered classrooms where students become passive recipients of information rather than active problem solvers. According to (Joyce et al., 2015), the learning model used by teachers strongly influences students' learning behavior and achievement. Therefore, capacity building and professional development for teachers in implementing innovative models such as STEM-based PBL are urgently needed. Teachers must be equipped not only with conceptual knowledge but also with the ability to design learning

that integrates real-life problems, digital tools, and inquiry-based approaches (Binkley et al., 2012; Hidayat et al., 2023).

However, the obstacle is that not all teachers can apply the STEM-based PBL learning model. This, in accordance with the results of a preliminary study at SMA Negeri Kesamben, information was obtained that the majority of teachers have not implemented the STEM-based PBL model. The learning that is often carried out in the high school class uses the Direct Instruction model and lectures. This is because teachers find it difficult to apply STEM-based PBL to global warming materials. Therefore, teacher-centered learning makes students feel bored and show passive behavior. Passive behavior carried out by students such as chatting with friends, playing cellphones during learning, and many permissions outside the classroom with excuses to go to the bathroom (Khadijah et al., 2025). In line with research by (Pasaribu et al., 2020) which states that teacher-centered learning will make students have low critical thinking skills. Therefore, to improve students' critical thinking skills, the application of the STEM-based PBL model is expected to improve critical thinking skills optimally. Based on the above background, a research was conducted with the title Improving the critical thinking skills of high school students through STEM-based LKPD PBL on global warming materials . This study aims to analyze the effectiveness of STEM-based PBL (science, technology, engineering, mathematic) LKPD in improving students' critical thinking skills, especially on global warming materials

B. Research Method

The research was conducted in class X of SMA Negeri Kesamben involving 36 students of class X who were selected by purposive sampling. This research was conducted in the even semester of 2024/2025 using a quasi-experimental design with a pretest and posttest model in one group (Creswell, 2014).

$$O_1 \quad \text{x} \quad O_2$$

The quasi-experimental design with One-Group Pretest-Posttest is a type of research that has a control class, but cannot fully function to control external variables that affect the implementation of experiments with samples not taken randomly (Sugiyono, 2022). In the design of this study, one group of class X students was assessed before and after the application of STEM-based PBL learning interventions on global warming materials aimed at measuring changes in students' conceptual understanding. The difference in pretest and posttest scores was analyzed to determine the improvement of students' critical thinking skills. The research instruments consisted of observation sheets, critical thinking ability test sheets, and response questionnaire sheets. The test was carried out with 10 questions that could measure students' understanding of critical thinking skills before and after STEM-based PBL learning. Quantitative data analysis where pretest and posttest results are analyzed using N-Gain to see

if there is a significant difference in students' critical thinking skills before and after the intervention (Hake, 1998). N-Gain analysis can be calculated using the formula:

$$N - Gain = \frac{Skor\ pretest - Skor\ posttest}{\text{Skor maksimum} - \text{Skor pretest}}$$

Table 1. N-Gain value criteria

N-Gain Value	Category
N-Gain > 0.7	Tall
0.3 ≤ N-Gain ≤ 0.7	Now
N-Gain < 0.3	Low

(Source : Meltezer, 2002)

C. Result and Discussion

Based on research that has been carried out on 36 students of class X of SMA Negeri Kesamben, the results of the comparison of pretest and posttest scores of students after using STEM-based LKPD PBL were obtained. The comparison of pretest and posttest scores can be seen in Figure 1.

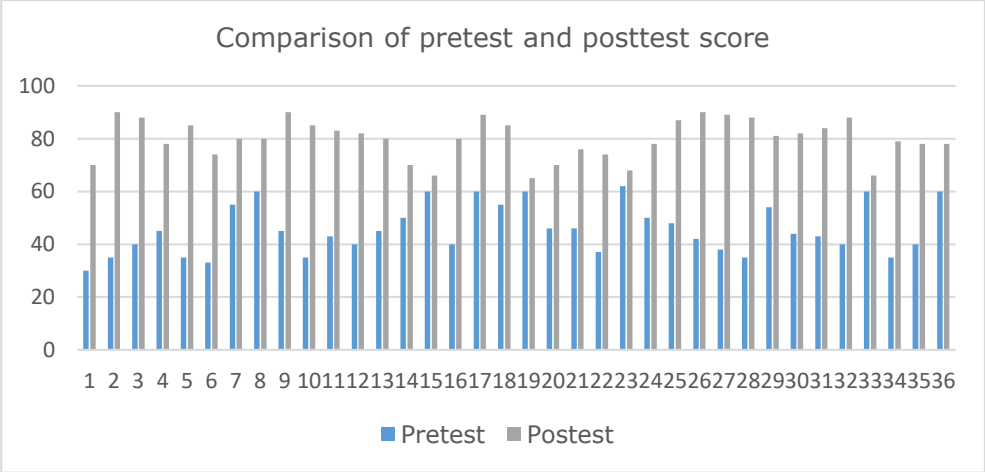

Figure 1. Comparison of pretest and posttest score

Group	N	Mean Pre-test	SD Pre-test	Mean Post-test	SD Post-test	t	p
Kontrol	18	45.72	8.45	79.89	7.62	14.27	0.000

Based on the data in Figure 1, there is a difference in the pretest and posttest scores of students before and after the STEM-based PBL learning intervention. Before the learning treatment

using STEM-based LKPD PBL, the majority of students had a pretest score in the low category with a score range of 30-62. After learning treatment using STEM-based LKPD PBL, there was a consistent increase in posttest scores, namely with a score range of 65-90. So based on the data in figure 1, it can be concluded that there is a significant increase in students after learning is applied using STEM-based LKPD PBL.

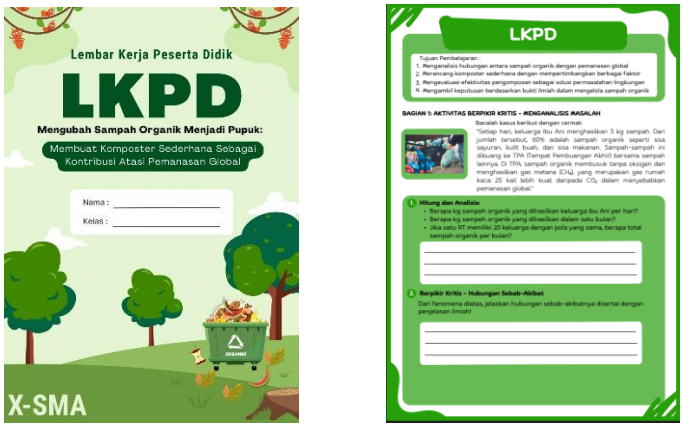

Figure 2. The PBL LKPD Global Warming Material

Furthermore, the N-Gain calculation aims to measure the improvement of students' critical thinking skills with the average pretest score of 45.72 and the average posttest score of 79.89. So that the average N-Gain obtained is 0.74, indicating an increase of 74.22%. Data on improving critical thinking skills can be seen in Figure 2.

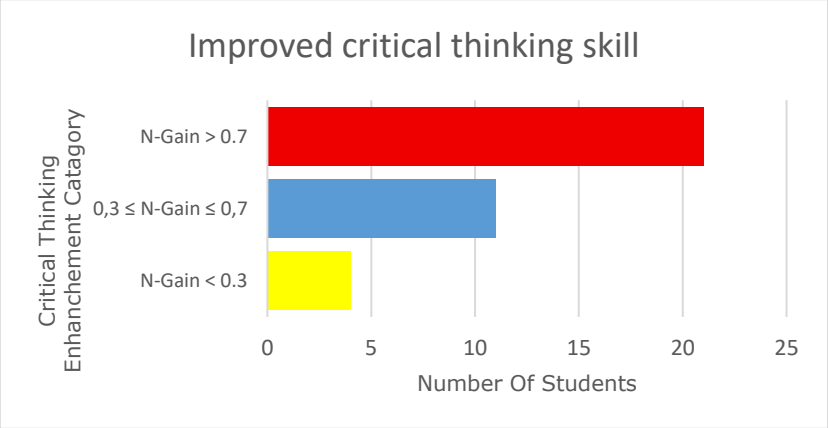

Figure 3. Improved critical thinking skill

Based on Figure 2, data can be obtained on the improvement of students' critical thinking skills as measured using the N-Gain value. The data showed that there were 21 students who experienced an increase in critical thinking skills in the high category (N-Gain > 0.7), where 11 students showed an increase in the moderate category (0.3 < N-Gain > 0.7) and there were 4 students who experienced an increase in critical thinking skills in the low category (N-Gain < 0.3). This shows that the majority of students experience a significant improvement in critical thinking skills after being given learning interventions using STEM-based LKPD Problem

Based Learning which can provide a more contextual and comprehensive understanding of global warming material.

STEM-based Problem Based Learning student worksheets (LKPD) have been proven to be effective and efficient teaching methods and learning resources in improving students' conceptual understanding and critical thinking skills on global warming materials. Based on the data obtained, there was a significant increase in students' critical thinking skills with an average pretest score that was originally low of 45.72 increasing to 79.89 in the posttest. This increase is reflected in the average N-Gain value of 0.74 which shows an increase in understanding by 74.22%.

The material used is about global warming. The elements of science studied are about climate change due to global warming which is triggered by human activities in littering so as to cause accumulation and pollution, so the main focus of learning in this study is how students can learn and produce a simple composter project to process organic waste into compost as one of the solutions to minimize high methane gas emissions in the world. school environment using a STEM approach. According to Muttaqin (2023), the STEM method, which stands for *Science, Technology, Engineering,* and *Mathematics*, emphasizes a balanced integration of these fields.

The following are aspects in the STEM approach (Kelley & Knowles, 2016), in this study the *science* aspect is a scientific investigation process which prepares students to think like scientists such as hypothesizing and conducting scientific investigations about the solution to the global warming problem by making a simple composter to process organic waste into compost so that the output can minimize methane gas emissions in the air.

The aspect *of technology* in this study is about technology literacy in its use activities for designing and manufacturing something. Students will later have a literacy understanding of technology that will be used in solving global warming. The *engineering aspect* in this case is related to the engineering design process that allows students to build knowledge of science and mathematics through the analysis of the design or design of procedures for processing organic waste into compost, namely a simple composter. The *Mathematic aspect* is the use of mathematical concepts or mathematical thinking in the process of scientific investigation related to the process of making simple composters.

The results of the implementation of learning using STEM-based LKPD PBL show that students experience an increase in critical thinking skills. Based on the results of the study, there was an increase in the average score with an N-Gain of 0.74 after implementing learning using STEM-based LKPD PBL. This indicates that learning using LKPD is effective in improving students' critical thinking abilities. The effectiveness of this approach can be seen from the significant improvement in students' analytical skills and engagement during the learning process. This is in line with research conducted by Iskandar et al. (2022), which shows that the

STEM (Science, Technology, Engineering, and Mathematics) approach can enhance students' analytical and problem-solving skills, making them more motivated and active in learning.

D. Conclusion

The implementation of learning using STEM-based LKPD with a Problem Based Learning (PBL) approach on global warming material proved to be highly effective in enhancing students' conceptual understanding and critical thinking skills. The results showed a significant improvement in students' ability to analyze, evaluate, and connect scientific concepts related to global warming. This finding suggests that the use of STEM-based LKPD PBL can be effectively applied in schools as an innovative learning strategy. In addition to strengthening students' higher-order thinking skills, this approach also fosters greater motivation and enthusiasm for learning, particularly in understanding complex environmental issues such as global warming.

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