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Enhancing Students' Learning Outcomes and Science Process Skills through STEM Project-Based Learning on Global Warming Topics

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Abstract

Global warming is a major concern, and tackling it via education is crucial. The purpose of this study is to investigate the impact of combining the Science, Technology, Engineering, and Mathematics (STEM) approach with the Project-based Learning (PjBL) model on students' learning outcomes and science process skills in global warming topics. The study, which used a one-group pretest-posttest design, collected data from 33 grade XI students via essay questions and observation sheets to assess learning outcomes and science process skills. Critical indicators of science process abilities were observing, classifying, interpreting, predicting, applying concepts, communicating, and forming conclusions. Students worked on a STEM-based project to build a flood-resistant house over the course of five meetings (including the pretest and post-test). The findings revealed considerable improvements: learning outcomes increased by 0.6 (medium category), while science process skills improved by 0.7 (high category). Observations revealed that pupils' scientific process skills were excellent. The Wilcoxon test revealed a significant difference between students' learning outcomes and science process abilities before and after the intervention, with a Sig (2-tailed) value of 0.000. The study indicated that combining the STEM method with the PjBL model improves students' learning outcomes and scientific process abilities. However, the small sample size implies that the results may not be generalizable. The consequence is that integrating the STEM method and the PjBL model provides an innovative option in physics education, improving learning outcomes and scientific process skills.

Keywords: global warming, learning outcomes, project-based learning, stem, science process skills

INTRODUCTION

21st-century skills are essential for students to have, especially at the senior high school level, in order to adapt to today's increasingly advanced world (Contreras-Espinosa & Eguia-Gomez, 2022). Science process skills require students to utilize the knowledge gained into ideas that can be used as a solution to a problem (Hacıeminoğlu et al., 2022). Scientific process skills cannot be possessed by themselves, but they need to be trained through the learning process experienced by students so that students can apply them in life (Hacıeminoğlu et al., 2022). Solé-Llussà et al. (2020) assert that the development of science process skills necessitates direct experience as a learning experience, and students need to recognize this during the learning process. The education curriculum in Indonesia also places a special emphasis on developing students' science process skills, as outlined in the 2013 curriculum and the independent curriculum. The 2013 curriculum sets an example by formulating essential subject competencies that not only emphasize cognitive but also psychomotor aspects, while the independent curriculum incorporates learning outcomes.

Soltani (2020) stated that selecting learning models or educational strategies can significantly influence students' science process skills and learning outcomes. Unfortunately, today, learning in schools tends to be passive and ineffective, whereas learning activities are still teacher-centered. According to a previous study (Erlinawati & Bektiarso, 2019), schools typically rely solely on the lecture method for all learning processes. To address this issue, teachers must select and implement effective learning models that encourage student participation and enjoyment in the classroom. This includes selecting learning models and techniques that align with the physics curriculum and the unique characteristics of the subject. One factor contributing to low learning outcomes and low student activity in physics learning is the lack of direct student participation in the teaching and learning process. This issue highlights the need for a learner-centered learning model that facilitates rapid knowledge sharing between students and teachers. In addition, students need to learn to work with classmates to solve a problem and develop their understanding of a concept.

Interviews with several students in a school in East Borneo Province revealed that many students remained uncertain about the value of studying physics, particularly in relation to global warming topics, as the teacher's explanations and practice questions dominated the subject. Students' lack of engagement in the learning process and tendency to become bored quickly can have a negative impact on their science process skills and learning outcomes. Therefore, teachers should implement learning models that directly involve students, fostering a more active and engaging learning environment to improve science process skills and student learning outcomes. The research conducted by Pradita et al. (2020) revealed that the underlying issue in schools is the infrequent application of learning models that align with the current curriculum in Indonesia. Most of the teaching process activities, including those related to global warming, lack student-centered learning and have a negative impact on students' learning outcomes. Our observations at a senior high school in East Kalimantan reveal that the learning activity merely requires students to study independently based on the theories found in reference books, resulting in a lack of student participation in the learning process and a lack of tangible solutions to the global warming issue.

Students with low learning outcomes and science process skills require a practical learning approach that encourages active learning and problem-solving discussions. The Science, Technology, EngineerAround the world, people widely use the Science, Technology, Engineering, and Mathematics (STEM) approach to enhance student learning outcomes and skills (Sulaeman et al., 2022). learning approach that fosters problem-solving skills (Purwaningsih et al., 2020). Both formal and informal settings can widely use STEM learning (Gupta et al., 2020). Applying the STEM approach to learning in schools is very important to foster 21st-century skills and meet the needs of today's learners (Asrizal et al., 2022). One of the components of STEM is science, and learning science involves principles, theories, laws, and process skills (Bhakti et al., 2020). Research by Farach et al. (2021), for example, indicates a significant difference in learning outcomes between the control class and the experimental class that applies STEM-based performance assessment to students' science process skills. The Project-Based Learning (PjBL) model can also integrate the STEM approach (Oyewo et al., 2022; Purwaningsih et al., 2020; Widarti et al., 2020). Dwikoranto et al. (2018) stated that the project-based learning model helps students explore, assess, interpret, synthesize, and collect information from various relevant sources to produce creative products to solve real-life problems. According to Padmadewi et al. (2023), a project-based learning model prioritizes students, emphasizing a more effective learning approach that encourages students to solve problems independently and produce authentic work as a result of their learning. A project-based learning model can improve students' learning outcomes and science process skills (Schneider et al., 2022).

Dwikoranto et al. (2018) mention that the project-based learning model is a learning model that helps learners explore, assess, interpret, synthesize, and collect information from various relevant sources to produce creative products using a real-life problem approach. Lawless & Gosselin (2023) asserted that the project-based learning model prioritizes students, emphasizing a more effective learning approach that encourages students to solve problems independently through authentic work. This statement is supported by research (Schneider et al., 2022) that mentions that project-based learning models can improve students' learning outcomes and science process skills.

Several studies have integrated the STEM approach with the PjBL model and demonstrated improvements in student learning outcomes. For example, Prajoko et al. (2023) found that the STEM-PjBL model enhances students' understanding of concepts and creativity. Other research indicates that STEM-PjBL improves critical thinking (Purwaningsih et al., 2020), problem-solving (Wangguway et al., 2020), metacognition (Mukaromah & Wusqo, 2020), and communication skills. However, the impact of STEM-PjBL on students' science process skills, particularly concerning global warming topics, remains unexplored. This study aims to apply the STEM-PjBL model in a student-centered learning environment to analyze its effect on student learning outcomes and science process skills. Specifically, the research questions are: How does STEM-PjBL learning influence the learning outcomes and science process skills of students in a school in East Borneo Province on global warming topics?

METHODS

This study aims to find out how students' learning outcomes and science process skills improve after applying the STEM approach to the project-based learning model on the topic of global warming. This study employs a pre-experimental design method, utilizing a one-group pretest and post-test research design (Fraenkel et al., 2018). Students receive treatment in the form of learning activities that utilize the STEM approach and the PjBL model, focusing on global warming topics. We conducted this research at a senior high school in Kenohan District, Kutai Kartanegara Regency, East Kalimantan Province, Indonesia. This research utilized a sample of 33 students. The study employed a saturated sampling technique. Since there was only one class at that school, we used all students in class XI MIPA as samples.

The STEM component consists of science, represented in concepts related to global warming; technology, represented in the selection of tools and materials for making simple flood-resistant houses; engineering, described in designing simple flood-resistant houses; determining project success criteria; and mathematics, represented in identifying variables that influence the durability of flood-resistant houses. The project-based learning model used in this study involves determining fundamental questions, preparing project plans and schedules, monitoring students' progress, testing results, and evaluating their experiences.

Learning Outcome

The instrument used to obtain data on student learning outcomes is through 8 essay questions. Data collection techniques for learning outcomes use test techniques given before and after treatment. The average value was then calculated for the data and grouped into the categories listed in TABLE 1 (Triana, 2021).

TABLE 1. Categories of Student Learning Outcomes

Score	Category
$90 \leq x \leq 100$	Excellent
$80 \leq x < 90$	Good
$70 \leq x < 80$	Moderate
$60 \leq x < 70$	Less
$0 \leq x < 60$	Very Less

Learning outcome data was also analyzed using the N-Gain Test to determine the improvement category in student learning outcomes (Hake, 1999). The equation for calculating N-Gain is presented in EQUATION 1:

$$N_{gain} = \frac{score_{posttest} - score_{pretest}}{score_{maximum} - score_{pretest}} \quad (1)$$

After obtaining the N-gain value, the improvement category is grouped with the criteria as presented in TABLE 2.

TABLE 2. N-Gain Category

Score	Category
$Ngain \leq 0.3$	Low
$0.3 \leq Ngain < 0.7$	Moderate
$Ngain \geq 0.7$	High

After the N-Gain Test, a Hypothesis Test was carried out, namely the Wilcoxon Test, because the data was usually distributed but not homogeneous. This test was carried out using SPSS. This test aims to find out whether there is a significant difference between student learning outcomes before and after being given treatment. The test criteria are: If the results obtained are > 0.05, then there is an average difference, or H_0 is accepted. If the results obtained are <0.05, there is a difference in the averages, or H_1 is accepted, and H_0 is rejected. H_0 means there is no significant difference between student learning outcomes before and after implementing the Project-based learning model. H_1 means there is a significant difference between student learning outcomes before and after implementing the Project learning model.

Science Process Skill

Data collection techniques for science process skills carried out in this study were test and non-test. The test technique used an instrument of 7 essay questions, and the non-test technique used an observation sheet instrument that contained indicators of science process skills. The study focused on indicators such as observing, classifying, interpreting, predicting, applying concepts, communicating, and drawing conclusions. The study was conducted for five meetings (including pretest and post-test). Data collection through test and non-test techniques was carried out separately. The essay questions on science process skills were given before and after applying the STEM approach integrated with the PjBL model, namely at Meeting 1 and Meeting 5. The observation sheet of science process skills was used to observe the emergence of science process skills indicators during the learning process (Meeting 2-4). Data analysis techniques for learning outcomes use test techniques, given before and after treatment, and non-test techniques by calculating the percentage of Science Process Skill indicators appearing in the learning process. 7 Science Process Skill indicators are observed, including the skills of observing, classifying, interpreting, predicting or proposing, applying concepts, communicating, and drawing conclusions. TABLE 3 show categories of students' science process skills.

TABLE 3. Categories of students' science process skills.

Score	Category
$80 \leq x \leq 100$	Excellent
$60 \leq x < 80$	Good
$40 \leq x < 60$	Moderate
$20 \leq x < 40$	Less
$0 \leq x < 20$	Very Less

K.P.S. test result data is processed and analyzed using the same test as student learning outcome data, namely the N-Gain Test and the Wilcoxon Test.

RESULTS AND DISCUSSION

The research data analysis, including data on students' learning outcomes and science process skills, showed an increase in learning outcomes and science process skills after applying the STEM approach integrated with the PjBL model.

Learning Outcomes

Data on student learning outcomes during the pretest can be seen in FIGURE 1. Based on FIGURE 1, we know that the minimum score obtained by students in the pretest is 18, and the maximum is 69.

The acquisition of the average pretest score is a value of 41.36 in the deficient category. Then, the post-test results can be seen in FIGURE 2.

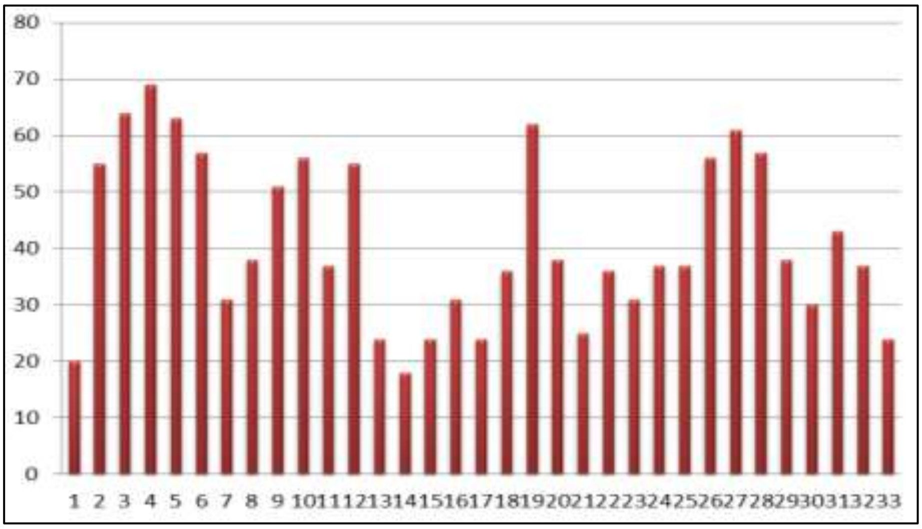

FIGURE 1. Pretest Learning Results

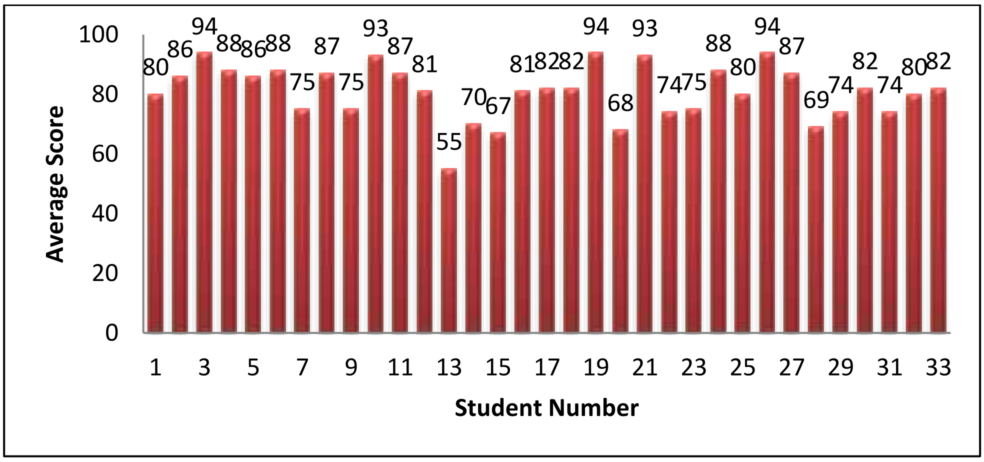

FIGURE 2. Pretest Learning Results

According to FIGURE 2, we can see that the minimum score obtained by students was 55, and the maximum was 94. The average pretest score was 80.94 in the excellent category. The results compare the significant increase in learning outcomes before and after implementing the project-based learning model.

The results of the N-gain test show whether there is an improvement or completeness between the pretest and post-test scores on the student's exam results.

TABLE 4. Obtained Learning Results from the N-Gain Test

Descriptive Statistics				
Class	Average pretest	Average posttest	N-gain	Category
XI MIPA	41.36	80.94	0.6	Moderate

Based on TABLE 4, there has been an increase in the average value of learning outcomes, with a score of 41.36, to a score of 80.94, and an increase in a score of 39.58. The pretest score obtained a minimum score of 18 and a maximum score of 69, while the post-test results obtained a minimum score of 55 and a maximum score of 94. The results obtained by the N-gain test in class XI MIPA science process skills were included in the moderate category.

The normality test in this research used the SPSS 22 for Windows program with the Shapiro Wilk method. TABLE 5 presents the data from the Normality test results for pretest and post-test student learning outcomes.

TABLE 5. Normality Test of *Pretest* and *Post-test* Learning Results data

Tests of Normality

Class XI MIPA	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest learning outcomes	.196	33	.002	.926	33	.028
Post-test learning outcomes	.126	33	.200*	.949	33	.121

Based on the data obtained in TABLE 4, the results of the data normality test had a significant pretest score of 0.028, and the post-test test results obtained a substantial value of 0.121. So, it can be concluded that the post-test results are normally distributed. The Homogeneity Test results obtained an average significant value of more than 0.05, so the results obtained the same or homogeneous variance, presented in TABLE 6.

TABLE 6. Test of Homogeneity of Variances

Learning outcomes pretest-posttest	Levene Statistic	df1	df2	Sig.
	13.068	1	64	.001

From the results of the normality and homogeneity tests, it is known that the data produced is normal but not homogeneous; this does not meet the requirements for conducting parametric tests; therefore, to analyze the hypothesis test, the Wilcoxon test is used, which is a non-parametric test used to measure differences in 2 groups using *SPSS 22*. The results of the Wilcoxon Test on student learning outcomes data are presented in TABLE 7.

TABLE 7. Wilcoxon test pretest and posttest.

Test Statistics

	Post-test – Pretest learning results
Z	-5.014[a]
Asymp. Sig. (2-tailed)	.000

Based on TABLE 7, a hypothesis test with the pretest and post-test results showed that the learning outcomes were worth negative z (-5.014). The results of the Wilcoxon test show that the value (2-tailed) of 0.000 is smaller than 0.05, so there is a significant difference between students' learning outcomes before and after STEM-PjBL is applied.

Padmadewi et al. (2023) states that the project-based learning model is a learning model that focuses on students with more emphasis on a more effective learning model, where students' learning activities are more independent in solving problems as a result of learning. Research also supports this statement (Schneider et al., 2022), which states that the project-based learning model can improve learning outcomes and science process skills.

The project-based learning model is a learning model where a student asks basic questions or general questions related to the material (Iserte et al., 2023) that the teacher will present to find out the initial knowledge possessed by the student and then guides the student in a mission that has stages in solving a problem in project form. Project-based learning is also a student-centered learning model system, so students are more collaborative and actively involved in completing projects independently, working together in teams, and integrating real and practical problems.

Science Process Skills

Data on students' science process skills were collected using two instruments: essay questions and the observation sheet of science process skills. The pretest score of each student during the pretest is presented in FIGURE 3.

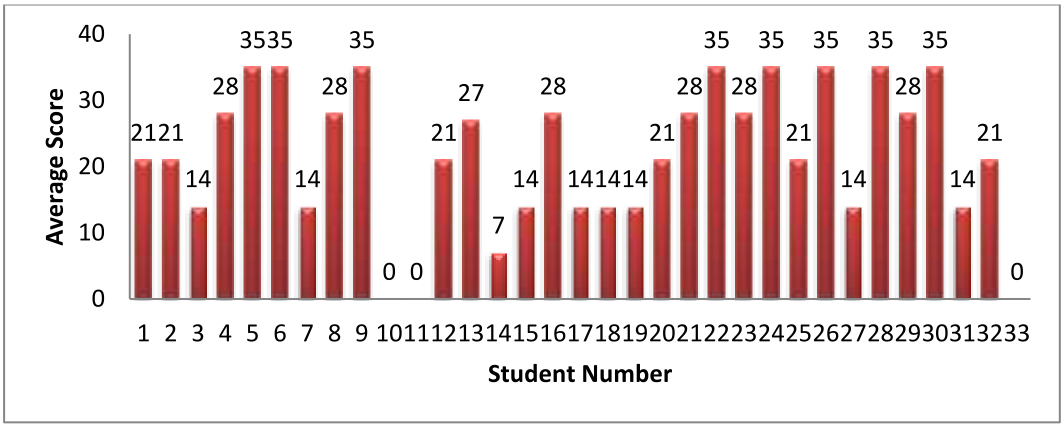

FIGURE 3. Results of the science process skills pretest.

The pretest results conducted by each student before applying the STEM-PjBL were still shallow, with a minimum score of 0 and a maximum of 35. Furthermore, the results of the post-test for science process skills that each student carried out after applying the STEM-PjBL showed a significant increase in results, as shown in FIGURE 4.

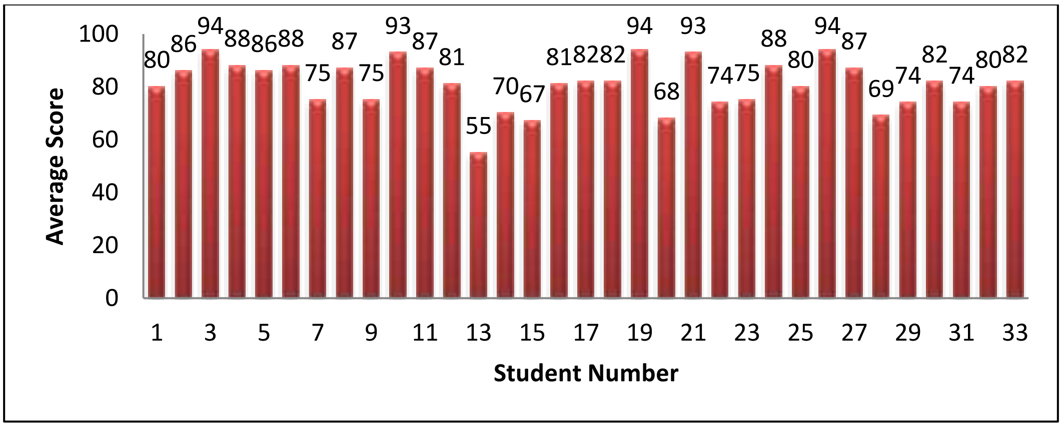

FIGURE 4. Post-test results of science process skills.

Based on FIGURE 4, the minimum score of students' science process skills was 63, and the maximum score was 93. The results of the N-Gain analysis of students' science process skills are presented in TABLE 8.

TABLE 8. Obtained results of science process skills from the N-Gain test.

Class	Average *pretest*	Average *posttest*	N-gain	Category
XI MIPA	21.81	81.03	0.7	High

Based on TABLE 8, it can be seen that there has been an increase in the average value of science process skills from a value of 21.81 to a value of 82.03 with an increase in value of 60.21, where the pretest value obtained a minimum value of 0 and a maximum value of 35. In contrast, the post-test results obtained a minimum value of 63 and a maximum value of 93; the results obtained from the N-gain test in class XI MIPA science process skills are included in the high category.

The results of the normality test on student science process skills are presented in TABLE 9.

TABLE 9. Normality Test of Pretest and Post-test Data for Science Process Skills

Class XI MIPA	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-test KPS	.139	33	.104	.900	33	.005
Post-test KPS	.241	33	.000	.902	33	.006

Based on the results of the science process skills data obtained in TABLE 9, it can be seen that the normality test results of the pretest score data were 0.05, and the post-test test results were 0.06. So, it can be concluded that the pretest and post-test results are normally distributed.

The results of the homogeneity test on student science process skills are presented in TABLE 10.

TABLE 10. Homogeneity test pretest and posttest.

Pretest- posttest KPS	Levene Statistic	df 1	df 2	Sig.
	7.138	1	64	.010

The results of the Wilcoxon Test on student science process skills are presented in TABLE 11.

TABLE 11. Wilcoxon Test

	Post-test – Pretest science process skills
Z	-5.016[a]
Asymp. Sig. (2-tailed)	.000

Based on TABLE 10, a hypothesis test was obtained with the pretest and post-test results showing that the science process skills obtained were worth negative z (-5.016). The results of the Wilcoxon test show that the value (2-tailed) of 0.000 is smaller than 0.05, so there is a significant difference between students' science process skills before and after STEM-PjBL is applied. Four observers assisted observations using observation sheets during the learning process, carried out at meetings 2-4. The essay questions were obtained from pretests at the beginning and post-tests at the end of learning. The following research instrument is an observation sheet with seven indicators: observing or observing, classifying, interpreting or interpreting, predicting or proposing, applying concepts, communicating, and drawing conclusions, carried out in class XI MIPA.

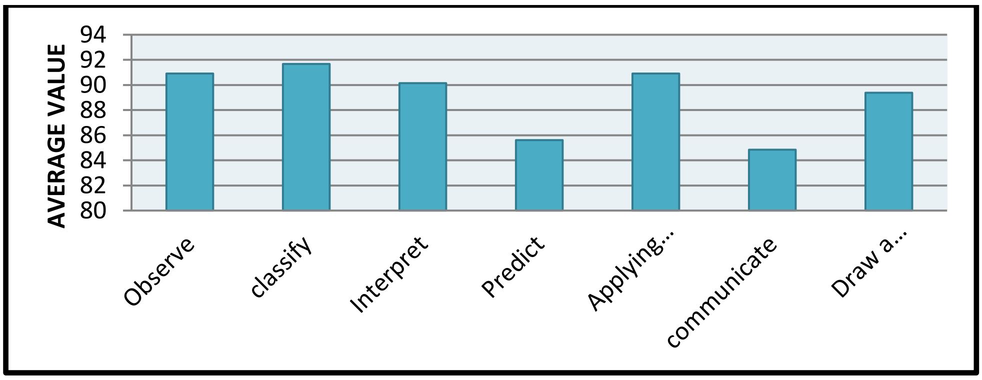

FIGURE 5. Observations of each indicator

FIGURE 5 shows that each indicator's average value of science process skills after calculating the overall score reaches the excellent category. Based on these results, the project based learning model can be declared effective for science process skills, this is because there are learning activities that make students experience new experiences, as stated by Miller et al. (2021). Learning with a project based learning model, namely learning can develop students' creativity, because in the learning process students are trained to solve problems alone or in groups. Students are also asked to create projects by involving students' imaginations and then expressing them in the form of interesting new ideas by realizing these creative ideas in the form of projects (Weng et al., 2022).

Science process skills can help students to practice solving problems starting from the skills of thinking (Emara et al., 2021) , reasoning (Kim and Pegg, 2019) and acting logically to researching and building scientific concepts. This statement is not appropriate because science process skills can also help students to practice designing a project, observing, grouping, predicting, concluding, applying concepts and communicating. Indicators of science process skills can improve the results of students' science process skills (Çakiroğlu et al., 2020) as seen from how students are starting to be able to predict (Lambert et al., 2020), make presentations of data included in activity reports, and students are able to conclude the objectives of learning. The study concluded that the Project Based Learning model is a student-centered learning model, so that students are more collaborative, and students are actively involved in completing projects independently and working together in teams and integrating real and practical problems so that they can improve students' science process skills. The following are the results of the project designs that students have made. FIGURE 6 show the design and FIGURE 7 show pictures of the project results that students have made.

FIGURE 6. Students' Design Project

FIGURE 7. Students' Project

In learning, students' activities are more independent in solving problems with authentic work as a result of learning both in groups and individually, so students find it easier to understand the learning material. This statement is supported by the research results of (Schneider et al., 2022), who stated that the project-based learning model can improve learning outcomes and students' science process skills. The results of this research are also in line with research by Hiğde and Aktamış (2022) which shows that applying a STEM approach can improve science process skills, and STEM activities can even foster a positive outlook on interdisciplinary education and 21st century skills. STEM activities are needed to be practiced because they will be useful in the future in the needs of the world of work (Vennix et al., 2018).

This research enriches learning theory by providing empirical evidence that integrating a STEM approach with the PjBL model can improve students' learning outcomes and science process skills, supporting constructivism theory, which emphasizes the importance of active learning and direct experience in understanding complex concepts such as global warming. This study shows that the STEM-PjBL approach is practical in teaching academic content and developing science process skills, which aligns with the theory that project-based learning can encourage student engagement and critical thinking. In addition, this research adds to the literature showing that STEM education can be implemented effectively at various educational levels and subjects, especially in physics education at the high school level.

Teachers can implement the STEM-PjBL approach in the classroom to improve student's learning outcomes and science process skills through projects relevant to everyday life, such as the design of flood-resistant houses. The education curriculum can also be updated to include more STEM-based projects that focus on global issues such as global warming, making learning more relevant and engaging. In addition, the results of this study can be used as a basis for teacher training programs, where teachers are trained to integrate the STEM approach with the PjBL model in their teaching.

Policymakers can consider integrating STEM approaches and PjBL models into national or local education policies by incorporating them into curriculum standards and providing the necessary resources. Governments and educational institutions can provide funding and infrastructure, such as well-equipped science laboratories, to support STEM-PjBL-based learning. In addition, the education evaluation and assessment system must be adjusted to emphasize science process skills and learning outcomes obtained through STEM projects, including developing assessment tools for students' abilities in various scientific skills.

CONCLUSION

Based on the research that has been conducted, it can be concluded that STEM-PjBL affects students' learning outcomes on global warming topics, indicated by an N-gain value of 0.6, reaching the moderate category. Furthermore, the STEM-PjBL also affects students' science process skills, as noted in the results of the observation sheet of student acquisition during learning, which is in the excellent category, and the N-gain value of 0.7 in the high category.

The limitation of this study is the small sample size consisting of only 1 class so that it cannot describe or represent the same results in a larger population. Future research can further explore the impact of the STEM-PjBL Implementation intervention in a broader sample and various other types of 21st-century skills.

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