Jurnal Penelitian Pembelajaran Fisika
Vol. 15 Issue 4 – October 2024, p418-424
p-ISSN 2086-2407, e-ISSN 2549-886X
Available Online at http://journal2.upgris.ac.id/index.php/JP2F
DOI: 10.26877/jp2f.v15i4.955

Implementation of a STEM-Based Project-Based Learning Model to Improve Students' Science Process Skills on Alternative Energy Material

Saskia Quraruaini Batrisyia[1,2], Irma Rahma Suwarna[1] and Winny Liliawati[1]
[1]Pendidikan Fisika FPMIPA Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung, Jawa Barat 40154, Indonesia

[2]E-mail: saskiabatrisyia@upi.edu

Received: 1 August 2024. Accepted: 26 September 2024. Published: 31 October 2024.

Abstract. Science process skills are skills that students must have in learning Physics because students are required to be able to apply scientific methods and knowledge and develop the knowledge skills they already have, so that science process skills are needed by students to face the real world which is dominated by technology and science. The purpose of this study is to ascertain how students' science process abilities in studying physics are affected by a STEM (science, technology, engineering, and mathematics) project-based learning approach. The study's sample was selected through the use of purposeful sampling. The sample consisted of thirty-four X grade students from a public high school in Bandung City. Formative pretest-posttest testing was used in this study as part of a quantitative pre-experiment methodology. Twelve multiple-choice questions were utilised in a formative evaluation of science process abilities to collect research data. The results revealed that the moderate group had an N-Gain score of 0.61. A high category for observing and classifying indicators and a medium category for forecasting, measuring, drawing conclusions, and presenting indicators are used to categorise the improvement in science process skills indicators. Thus, the STEM-based learning model can improve students' science process skills.

Keywords: *project based learning*, *STEM, PjBL-STEM, science process skills*

1. Introduction

Education is very important for human life and the progress of the nation. One important aspect in the development of students' intellectual education at school is science education, one of which is physics learning. Physics is a scientific discipline that investigates natural phenomena and phenomena related to human existence. Physics also teaches students to reason rationally and mathematically. Physics learning is very important for various reasons related to improving knowledge, skills and attitudes [1]. The skills that students must have in learning science, especially physics, are science process skills. In physics learning, students are not only required to be able to master the content but also must contain products, processes, attitudes and technology as well as students' understanding of physics to be intact and can be useful to solve the problems they will face. [2]. One science process skill is the scientific method. Students who are proficient in science process skills must apply science and the scientific method to expand on prior knowledge. In order to thrive in a society where science and technology rule, learners must possess science process skills [3]. So that kids may participate in physics learning by having science process skills.

According to a research by Ifa et al. that used a five-item description exam that was provided to a Bandung City high school, 24% of pupils lacked basic science process abilities [4]. According to Murni's research, between 40% and 60% of students have science process abilities that fall into the intermediate range, meaning that teachers need to pay extra attention to this area [5]. Low science process skills in students are the result of inappropriate learning models or methods, while the literature claims that low science process skills in Physics learning are caused by a lack of student-involved learning optimization. Students have also not received the best instruction possible in science process skills during daily learning [6]. The STEM method is one of the appropriate teaching strategies used in scientific education, particularly in physics education. Through the learning process, students may immediately apply the principles they have learnt in STEM-based learning to their everyday lives. STEM-based learning involves activities that require students' science process skills, such as measuring, observing, classifying where students involved in STEM learning will learn to make systematic observations, collect data, and draw conclusions based on the results of their observations and experiments, which is in line with the definition of science process skills which includes the ability to examine phenomena in a certain way to obtain knowledge and further scientific development [7]. STEM-based learning (*Science, Technology, Engineering, and Mathematics*) trains a variety of learner abilities, one of its advantages is the improvement of scientific attitudes and scientific processes [8]. With STEM learning, learners are asked to observe the natural and social conditions around them then learners will be invited to hone their literacy skills, where learners will sharpen previously owned science concepts. Then students will solve problems and create solutions in the form of technological products through a series of previously honed science and finally students carry out scientific processes and attitudes to solve problems faced in their environment [9]. One of the learning models that can be integrated with STEM is project- based learning.

One of the models or activities for project-based learning that helps students acquire the necessary attitude, knowledge, and skill sets is project-based learning. The project itself can be understood as a labour-intensive task that calls for excellent collaboration between teachers and students in order to be completed [10]. On the other hand, project-based learning, which is associated with STEM areas (science, technology, engineering, and mathematics), emphasis on using real-world projects to solve issues pertaining to STEM fields. This PjBL-STEM lays a heavy focus on the real world to assist students retain the knowledge and skills they acquire and to help them reflect on the processes they take in problem solving [11]. This STEM project learning or learning by doing technique is based on constructivist philosophy [12]. Research has demonstrated that PjBL-STEM enhances students' performance in higher order cognitive activities, such solving mathematical problems and engaging in scientific procedures [13]. Students studying physics not only get conceptual understanding but also learn how to become proficient in scientific method and apply it to a project. Because they actively participate in their education, students can develop markers of science process abilities and become more conscious of the subject being taught.

Science process skills are closely related to the STEM-based project-based learning model (Science, Technology, Engineering, and Mathematics) which emphasizes active and learner-centered learning by involving learners in scientific or technology-based projects that are similar to real-world problems. Science process skills include a number of competencies that are very relevant to the PjBL- STEM learning model such as encouraging students to focus on scientific discovery, providing direct experience in applying concepts in real situations, involving critical thinking skills, challenging students to solve complex problems in the real world [14].

Several studies by past academics, including one by Nurliza and Dwi Agus, have produced findings that indicate the PjBL-STEM model influences students' science process abilities related to effort and energy. It is also known that using the PjBL-STEM approach to physics instruction might enhance students' science process abilities [5]. Furthermore, a number of additional researchers concur that using the PjBL-STEM paradigm improves students' science process abilities [15]. Nonetheless, prior researchers assessed integrated science process skills in similar investigations. Therefore, the skills used in this study are fundamental skills because it is crucial to provide students with these fundamental science process skills as a basis for learning more complex integrated skills that are appropriate for their high school abilities. These skills include classifying, observing, measuring, predicting, drawing conclusions, and communicating [16].

Due to the difficulties researcher has noted, the author feels that diverse learning is crucial to improving students' capacity for science process. The author conducted research on the use of the

STEM-based Project Based Learning Model to enhance students' science process abilities on alternative energy material (Science, Technology, Engineering, and Mathematics). The aim of this research is to determine the extent to which the STEM-based project-based learning paradigm enhances students' science process abilities.

2. Methods

This study used a pretest-posttest design with a single group and a quantitative pre-experiment methodology. In this kind of research, tests are administered to a single group (class) both before and after therapy. One class from one of Bandung City's public high schools was employed in the study. Thirty-four students participated in the research. Prior to receiving therapy, students completed a pretest at the first appointment in order to gauge their baseline scientific process skills. Following that, students received instruction using a STEM-based project-based learning methodology focused on materials related to alternative energy. A posttest was given to the students at the last meeting. This is the research design [17].

Table 1. One group pretest-posttest research design.

Pretest	Treatment	Posttest
O_1	X	O_2

From table 1 O_1 as Pretest, O_2 as Posttest and X as Class treatment, teaching and learning activities that use the problem-based learning model integrated predict, observe, explain.

Three phases served as the foundation for this study project: preparation, execution, and completion. Creating learning tools in the form of science process skills test instruments, student worksheets and teaching modules (LKPD), and feasibility testing of instruments are all part of the planning stage. Pretest, STEM-based learning model application on alternative energy material, and posttest on science process skills comprise the implementation step. Student complete projects and group work on worksheets as they are studying. Data processing, analysis, and discussion together with study conclusions are the last steps. The findings of the students' science process skills exam and their questionnaire responses provided the research data. Twelve multiple-choice questions that were created based on markers of science process abilities made up the formative assessments. Observing, categorizing, measuring, forecasting, drawing conclusions, and communicating are the indicators that are tested in this exam. Pretest and posttest scores are evaluated and computed before beginning data analysis. The N-Gain test will then be used to analyze the pretest and posttest findings. The following equations and categories below will be used to compute the N-gain value once the students' scores have been determined [18].

$$N - Gain = \frac{posttest\ score - pretest\ score}{maximum\ score - pretest\ score} \times 100\% \quad (1)$$

Table 2. N-Gain value category.

N-Gain value <g>	Category
$g < 0.3$	Low
$0.3 \leq g \leq 0.7$	Medium
$g > 0.7$	High

3. Result and Discussion

The STEM-based project-based learning approach is the therapy used in this study for classroom instruction. In order to say that treatment is effective, the goal is to increase students' scientific process abilities. Every phase of the study process went quite well and without hiccups. From the pretest and posttest data of students' science process abilities, the normalized N-gain may be computed to determine the high and low growth in science process skills utilizing the STEM-based project-based learning paradigm (Science, Technology, Engineering, and Mathematics). Table 2 displays the N-Gain processing results.

Table 2. Overall N-Gain results.

Average Pretest Score	Average Posttest Score	<g>	Criteria
5.909	9.515	0.592	Medium

The results of the science process skills exam taken by the students are displayed in Table 2 above. Their gain value of 0.592 was within the medium level. The results shows that students' science process abilities have improved after utilizing the STEM-based project-based learning paradigm (Science, Technology, Engineering, and Mathematics). In particular, all of the study's metrics demonstrated an increase in participants' science process abilities. The curve illustrating the development of science process abilities is shown in Figure 1. The category of improvement for each science process skills measure is shown in Table 3.

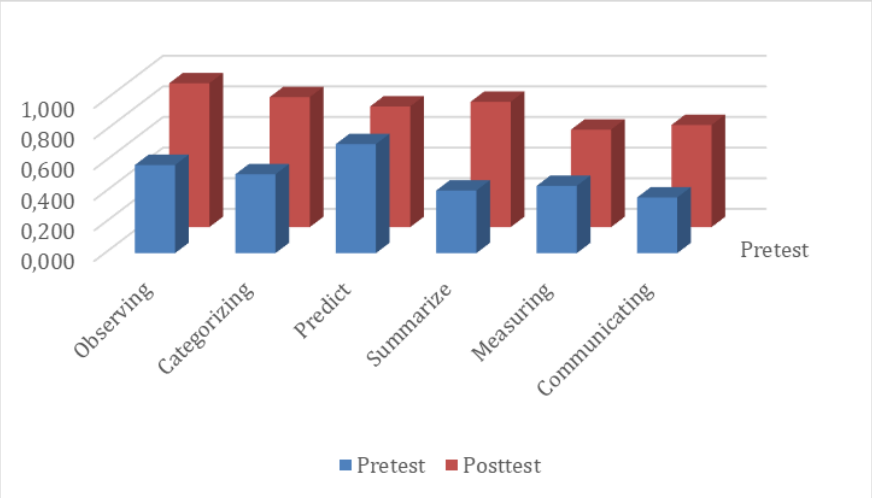

Figure 1. Graph of Average Improvement of Pretest and Posttest Indicators.

Tabel 3. Improvement of each indicator of science process skills.

No.	Science Process Skill Indicators	<g>	Category
1.	Observing	0.87	High
2.	Categorize	0.68	Medium
3.	Predict	0.59	Medium
4.	Summarize	0.68	Medium
5.	Measuring	0.38	Medium
6.	Communicating	0.48	Medium

With an N-Gain score of 0.87 in the high category, the observation indicator has the greatest gain score, according to Table 3. The measuring science process skills indicator, which was 0.38 in the medium group, saw the lowest N-Gain gain, nonetheless.

In the observation indicator, learners are able to obtain the highest increase. Learners are able to use as many senses as possible to observe and analyze phenomena. Where in each syntax students are trained in observing skills with the help of media such as simulations and videos that students need to observe properly to answer the questions on the student worksheet. In this observing activity, based on observations during learning, students are quite serious in observing each simulation and can record their observations on the worksheet that has been given. The increase in observing indicators is also in line with research conducted by Aulia, stating that classes that use STEM-based project-based learning models in learning have higher observation scores than classes that use other learning models.

In the grouping indicator, learners are asked to look for differences and similarities, contrast characteristics, compare and find the basis for classification. Learners in the reflection syntax are instructed to use this grouping indication. Here, using digital resources like simulations and learning materials for student workbooks, students are taught how to categorise talents. The grouping indicator grows with the "medium" category when the pretest and posttest results are compared to the N-Gain score of the grouping indicator, which comes out to be 0.68. According to the analysis of the posttest results, students were able to identify and contrast the two phenomena that were presented, as well as the advantages of two different power plants. Few students had any trouble answering these questions, and they were also able to group the students according to specific criteria. This grouping indicator has increased, because, in the learning process assisted by the media of the student worksheet (LKPD), students have been able to compare and find the basis for classification based on their observations. The following is a snippet of students' answers on the worksheet.

Setelah kamu melakukan eksplorasi pada simulasi PhET bentuk energi dan perubahan energi isilah tabel dibawah ini. Tentukan manakah yang termasuk kedalam sistem 1 dan sistem 3.

Sistem 1	Sistem II	Sistem III
Sepeda yang digerakkan	Generator	Lampu Bohlam
Matahari	Panel Surya	Kipas
Air	Generator	Lampu Bohlam
Uap	Generator	Kompor
Matahari	Panel Surya	Lampu neon

Figure 2. Extract of Learner's Answer.

Judging from the snippet of the picture above, students have been able to classify systems in the PhEt simulation based on the category of each system. The increase in categorizing indicators is also in line with research conducted by Rahman, et al., revealed that the grouping indicator has the highest percentage because this indicator is often experienced by students in everyday life, and has been trained in learning, especially science learning [19]. Djafar, et al., also revealed that the grouping indicator got the highest results, thus proving that students have a good ability to classify and classify data in accordance with the observation process [20].

In the prediction indicator, students are asked to be able to predict what might happen in situations that have not been observed properly and can make more accurate predictions or forecasts based on the data obtained or data that has been presented. This indicator has increased, one of the factors that influence it is because students are trained to find knowledge independently, one of which is through discussion activities in groups. Based on learning activities, almost all learning activities in the study were carried out in groups so that students were more active in discussing with their groupmates. The increase in predictive indicators is also reinforced by research conducted by Neyla, et al, which states that during the learning process students are taught to find their own knowledge from discussion activities [2].

In the conclusion indicator, students are asked to be able to make conclusions and provide explanations based on their observations. This indicator is trained to students in the syntax of research and discovery. Where in each syntax, students are trained on these indicators with the help of digital media and learning media in the form of simulations and student worksheets. This indicator is also trained to students at the final stage of making the project in the form of making conclusions about the success of the project that has been carried out. The pretest and posttest results compared to the N-Gain score get a value of 0.74 so that the observation indicator increases with the "medium" category.

Figure 3 concluding indicator has increased, because, seen in the snippet of answers to the student worksheet (LKPD) during the learning process, students have been able to make conclusions and provide explanations based on their observations, and students have been able to assess the final results of a project they have made. This also agrees with research conducted by Chasanah, that emphasizing product results can affect science process skills on the conclusion indicator because at that stage students conclude the results of the project work they have done [3].

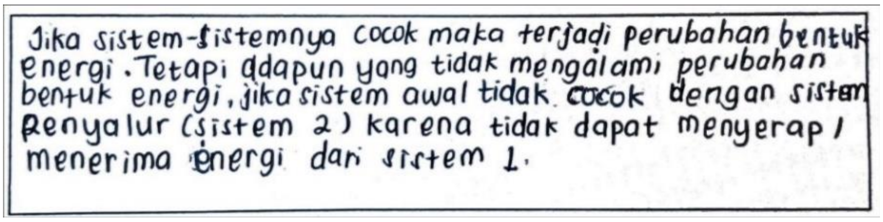
Jika sistem-sistemnya cocok maka terjadi perubahan bentuk energi. Tetapi adapun yang tidak mengalami perubahan bentuk energi, jika sistem awal tidak cocok dengan sistem penyalur (sistem 2) karena tidak dapat menyerap / menerima energi dari sistem 1.

Figure 3. Snippet of LKPD Answer.

Learners are expected to be able to gather data more precisely and compute observational outcomes more precisely in the measuring indicator. The grammar of reflection, study, and application is taught to this indication. whereby instructional resources in the form of worksheets are used to teach students on these signs in each syntax. Students are also instructed on this indicator during the project creation phase. When the pretest and posttest results are compared to the N-Gain score, the observation indicator rises in the "medium" category, with a value of 0.38. Many pupils have successfully identified patterns of correlations between data and are able to compute them based on their examination of the provided items. Nonetheless, a considerable number of pupils were also able to provide accurate answers, resulting in the rise being placed in a low category with an N-Gain score of 0.05. Based on observations made during the learning process, a considerable number of students struggle to identify patterns and relationships among the data that has been presented. These findings are derived from the analysis of the students' worksheet (LKPD).

Students must be able to describe in writing or verbally the findings of their observations in the form of words, graphs, charts, or tables for the communication indicator. Students are taught how to use this communicative indication in the communication syntax by having them deliver the outcomes of their group conversations. From the analysis of the items given, students can read the energy changes in a given simulation, but there are also some students who have difficulty answering these questions, because these items have a high level of difficulty, and students have also been able to explain the graph of the relationship between speed and kinetic energy, but not a few students also have difficulty explaining the graph. As part of the learning process, students may summarise their observations using tables and have group discussions in addition to being able to examine the results of the exams they have taken. Certain students, working in groups, are proficient in presenting their project outcomes when it comes to project execution. According to study by Surya Jatmika et al., learning with the STEM-based project-based learning paradigm can enhance science process abilities on the communication indicator [9].

4. Conclusion

Students' science process abilities have increased after utilizing the STEM (science, technology, engineering, and mathematics)-based project-based learning paradigm. Information about the increase may be obtained by looking at the pre-post test results and the N-Gain test. The "medium" group of the research had an N-Gain score of 0.61. Thus, it is possible to draw the conclusion that project-based learning approaches focussed on STEM subjects—science, technology, engineering, and math—can help students improve their knowledge of the scientific method. For a scientific skill indicator, every N-Gain score is unique. An N-Gain score of 0.87 was obtained for the observation indicator, 0.68 for the grouping indicator, and 0.59 for the prediction indicator. The concluding indicator received an N-Gain score of 0.68, the measuring indicator received an N-Gain score of 0.38, and the communicating indicator received an N-Gain score of 0.48. All indicators have increased in the high and medium categories.

Acknowledgement

We would like to thank the physics education lecturers of Universitas Pendidikan Indonesia for guiding the research and all the residents of SMA Negeri Bandung City for supporting and assisting the author in completing this research.

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