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The Effectiveness of using the Project-Based Learning Module Viewed from The SEPs Skills of Students

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Abstract

This study is intended to determine the effectiveness of using the project-based learning module viewed from the Science and Engineering Practices (SEPs) skills of students. The study employs a one-group pretest-posttest design involving 35 students of SMAN (State Senior High School) 1 Andong. There were six aspects of SEPs use in this study: asking questions and defining problems (SEP-1), developing and using models (SEP-2), planning and carrying out investigations (SEP-3), analyzing and interpreting data (SEP-4), constructing explanations and designing solutions (SEP-6), and Obtaining, evaluating and communicating information (SEP-8). The question instrument in this study was 13 two-tier multiple-choice (TTMC) test items developed corresponding to the science and Engineering Practices skills indicators in California Science Test Practices. The results of the study uncovered that the N-Gain value was 0.52, which means that the increase in the students' SEPs skills was in the medium category. The enhancement of each aspect of SEPs N-Gain was SEP-1: 0.54; SEP-2; 0.54; SEP-3: 0.49; SEP-4: 0.51; SEP-6: 0.53; and SEP-8: 0.56.

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INTRODUCTION

Education in the 21st century is one of the hot topics discussed, one of which is in the science field. It is because science in the 21st century is essential; however, it is more important how to apply it. This century's vital agenda is to create a generation with high quality to face the industrial revolution 4.0 0 (Rusdin, 2018). This high-quality generation is supported by skills, including collaboration, communication, professionalism, problem-solving, innovation, creativity, critical thinking, flexibility, business and management, digital literacy, agility, initiative, productivity, accountability, leadership, responsibility for practical intelligence, high ethical standards, dynamics, and resilience (National Academy Of Engineering, 2004; Trilling et al., 2004). Another focus is on Indonesia's education, which is oriented towards developing human resources (Zubaidah et al., 2017). It is in accord with Indonesia's education objectives, namely, to create creative, innovative, productive, and competent human resources to develop skills, attitudes, and knowledge (Depdiknas, 2013).

High-quality generations can be created by innovating in learning. One of them has been developed in physics education (Lazzaro, 2015) to make the latest physics learning goals called next-generation science standards, often referred to as NGSS. This NGSS is expected to improve students' abilities in learning science, technology, engineering, and mathematics (STEM) (Next Generation Science Standards & Barakos, Lujuan, Strang, 2012). This NGSS not only represents a set of updated science standards but is also repackaged (Atwood-blaine, 2017). NGSS provides students ongoing opportunities from primary to secondary school to develop and engage a more profound comprehension of the three science dimensions. This NGSS has three dimensions that will be developed: Scientific content (core ideas of the subject), scientific applications (engineering and scientific practice), and ideas that connect scientific subjects (concepts)(Next Generation Science Standards, 2013).

In learning science, especially physics, to develop students' skills, it is essential to foster the skills of science process. Science and Engineering Practices (SEPs) are the repetition of the term science process skills (Karadan & Hameed, 2016)or scientific inquiry skills in the previous version of science standards (Brand & Atwood-blaine, 2020). A gap exists between students' knowledge and skills learned at school and those needed in daily life (Gura & Percy, 2005). As indicated by NGSS using the term "practice" as well as "skills", performing scientific inquiry involves not only procedural skills but also conceptual understanding, which is specific to each discipline (Hynes-Berry & Berry, 2021). SEPs skills consist of eight aspects (Next Generation Science Standards, 2013):

1. Asking questions and identifying problem [SEP-1]
2. Developing and using models [SEP-2]
3. Planning and carrying out investigations [SEP-3]
4. Analyzing and interpreting data [SEP-4]
5. Using mathematics and computational thinking [SEP-5]
6. Constructing explanations and designing solutions [SEP-6]
7. Engaging in argument from the evidence [SEP-7]
8. Obtaining, evaluating, and communicating Information [SEP-8]

The description of each aspect is as follows , asking questions and defining problems (SEP-1) includes posing questions about data, statements, and design (National Research Council, 2011). Asking questions and defining problems starts with questions about phenomena to enhance theories to give explanatory answers to the second question (Ames et al., 2017). Developing and using models (SEP-2) includes drawings and diagrams used to represent the system being studied, help explain, generate data, predict, and communicate ideas to others (National Research Council, 2011). The phenomena described and analyzed can be explained using diagrams, replicas, simulations, and analogies (Duschl & Bybee, 2014). To construct and implement models to foresee and exhibit the connections among systems and their elements in the natural world is the SEP-2's practice(Stephenson et al., 2020).

Planning and carrying out an investigation [SEP-3], namely designing skills that involve students in making decisions to determine the steps from question to action, or in other words, design surveys to write experiments (Duschl & Bybee, 2014)(Stephenson et al., 2020). Analyzing and interpreting data [SEP-4] is a skill to process data; after the data is collected, the data must be presented in an easy-to-understand form to reveal relationships and patterns and allow them to be shared to others (Brand, 2020). Constructing explanations and designing solutions [SEP-6] is one of the science's goals. The purpose of science is to construct theories that provide explanations; a theory will be accepted if it has a lot of evidence and explanations that are stronger and bigger than previous theories, ideas, and principles (Stephenson et al., 2020). Obtaining, evaluating, and communicating information [SEP-8] includes the capability to read, interpret, and communicate clearly and persuasively (National Research Council, 2012). Other skills are obtaining, evaluating, as well as communicating evidence, information, and thoughts by means of various ways (Stephenson et al., 2020).

The NGSSand framework's vision is students utilize SEPs as a methods to exhibit that they are able to implement their knowledge for more significant learning experiences (Stephenson et al., 2020). This study used six SEP aspects: SEP-1; SEP-2; SEP-3; SEP-4; SEP-6; SEP-8 on work and energymaterials. Work and energy materials are materials that students learn from elementary school to middle school. Physics classes on middle school work and energy concepts have a wide range and are widely used in daily life(Lindsey et al., 2009). Therefore, students need to study the material more deeply.

One of the learning methods that can be applied to enhance students's skills is project-based learning. Project-based learning used in research has been packaged in a learning module so that the students learn it easier. The use of modules also provides direct learning experiences for students so that their skills can be accommodated properly One learning method that can be applied to improve student skills is project-based learning. Project-based learning used in research has been packaged in a learning module so that students learn it easier. The use of modules also provides direct learning experiences for students so that their skills can be accommodated properly.

This study is different from previous studies because in previous studies the researchers used project-based learning to improve SEPs skills (which are limited to one or two aspects) through learning tools such as lesson plans and student worksheets (Hapsari & Rosana, 2019) (Nursaida et al., 2020)(Maryani et al., 2017)(Santoso, 2019)(Kusumaningrum & Djukri, 2016). So the researchers made research with novelty in the form of making project-based learning modules to improve six aspects of science and engineering practices.

METHODS

This research is intended to determine the effectiveness of using the project-based learning module viewed from the SEPs skills of students. The study employs a one-group pretest-posttest design involving 35 students, there are consist of 25 female and 10 male of SMAN (State Senior High School) 1 Andong.The data were collected using a test technique with a Two-Tier Multiple Choice (TTMC) instrument. TTMC was first developed by David Treagust (1988) from Curtin University in Australia(Treagust, 1988).

This test instrument consisted of two levels. The first level was the main question, often known as the first tier. The second level was the reason why choosing answers to the main questions and often referred to as the Second Tier (Treagust, 1988). Two-tier multiple choice is like a multiple-choice question in general, what distinguishes it is that this TTMC question requires students' high-level thinking and skills' fostering to give reasons (Adodo, 2013). This study only used six aspects of SEPS skills, the indicators for six aspects of SEP are presented in Table 1 and were distributed into question numbers, as in Table 2.

Table 1. SEPs Aspect Indicators

Aspects of SEPs	Sub Indicators
Asking questions and defining problems	Posing questions that arise from the observation of phenomena precisely
	Asking questions to show connections, including quantitative connections between independent and dependent variables
Developing and using models	Comparing models to identify a variable
	Using information to make a prediction
Planning and carrying out investigation	Identifying the variables used
	Determine the tools and materials used in the experiment
	Compiling the experimental work steps
Analyzing and interpreting data	Organizing (making tables, graphs) of the results of experiments obtained

Aspects of SEPs	Sub Indicators
Constructing explanations and designing solutions	Analyzing graphs Creating models to build knowledge
Obtaining, evaluating, and communicating information	Analyzing the hypothesis Expressing idea

Table 2. Distribution of Problem Item Science and Engineering Practices

Assessment Indicators	SEPs Aspects					
	1	2	3	4	6	8
Presented a phenomenon, students can identify questions that can be tested.	1					
Presented an experiment, students can determine questions to know connections between dependent and independent variables.	2					
Presented a schematic of a tool about an experiment, students can choose the right image to compare certain variables.		3				
Use the information to make predictions		4				
Presented an experimental design, students identify the types of variables that are in the experiment.			5			
Presented the experimental tools and materials, students are asked to determine the tools and materials that are in accordance with the objectives of the experiment.			6			
Presented the experimental steps, students can determine the appropriate experimental steps.			7			
Presented the experimental data, students can make tables, graphs, and analyze the data.				8		
Presented a graph about the experiment, students can interpret the data from the graph.				9		
Presented an experimental picture, students can determine the effect of a variable.					10	
Presented an experimental table, students can determine the value of a certain quantity.					11	
Presented experimental design data, students can identify the appropriate hypothesis.						12
Presented with information, students can put forward an idea correctly.						13

The evaluation of the two-level multiple-choice tool uses a graded response model (GRM) method. GRM is a model developed to assess polytomous question items(De Ayala & Santiago, 2017).The rules for assessing the TTMC instrument(Wardani et al., 2015)are presented in Table 3.

Table 3. Rules for the Assesment of TTMC Instruments Using the GRM Method

No	Assessment Aspects		Score
	First Tier	Second Tier	
1	Not answering questions or wrong answers	Not choosing the reasons, or the wrong reasons	0
2	Wrong answer	Right reason	1
3	Correct answer	Wrong reason	2
4	Correct answer	Right reason	3

The assessment of students' SEPS skills using the GRM method made it easier for teachers to give grades. Besides, teachers could also recognize students' understanding from choosing answers to the first and second-tier problems. Therefore, this instrument could help teachers see students' initial skills (Ratnasari et al., 2017)and detect the skills of students (Wardani et al., 2015). The scores from the TTMC obtained by students were then converted into four categories (Sugiyono, 2016), which are presented in Table 4.

Table 4.*The categorization of students' SEPs Skills Score*

Percentage	Category
75% < P ≤ 100%	High
50% < P ≤ 75%	Medium
25% < P ≤ 50%	Low
0% < P ≤ 25%	Very low

RESULTS AND DISCUSSION

The first research stage is pretest procurement. The next stage is the application of the physics module for the learning process. After all learning activities are carried out by the students; it is followed by giving a posttest to them.The SEPs skill data consisting of six aspects are measured using a pretest and posttest. Data on the results of the skills test can be seen in Table 5.

Table 5. Data Description of the SEP skill Test Results

Type of test	Pretest	Posttest
Number of students	35	35
Average	42,27	70,62
Minimum Value	17,95	41,03
Maximum Value	66,67	97,44

Table 5 presents the data on the results of the SEPs skills test of students before and after being given a physics module based on project-based learning developed by the researcher. Based on the table, it can be seen that the SEPs skill score of students after using the module is higher than before using the module.

The pretest and posttest scores use to determine the effectiveness of module developed by researchers in improving SEPs skills. The Module effectiveness calculated using the normalized n-gain test. The N-gain score is 0.52. Based on the criteria proposed by(Hake, 1998), it concludes that project-based learning was effective for improving the skills of SEPs (Maryani et al., 2017). The improvement in the results of students' SEPs skills tests was categorized as moderate.

The improvement of the SEPs skills results is categorized as the medium because the students obtain project-based learning for the first time. They previously only obtain a lecture method, so they need to adjust to the new learning method in which consisted of SEPs aspects.

After the normalized N gain is calculated, the prerequisite tests of normality, homogeneity, and paired sample T T-test will be performed, as shown in Table 6.

Table 6. The Analysis Results of Pretest and PosttestS core

Test	Significance	Conclusion
Normality	Pretest = 0,685 Posttest = 0,260	Normally distributed data
Homogeneity	0,407	Homogenous Data
The differences between Pretest and Posttest results	0,000	Difference exists between Pretest and Posttest

Furthermore, an analysis of the increase in scores for each aspect of SEPs skills is presented in Table 7.

Table 7. The Average Results of the Increase of SEPs Skill Aspects

Aspects of SEPs	N-Gain	Category
SEP-1	0.54	Medium
SEP-2	0.54	Medium
SEP-3	0.49	Medium
SEP-4	0.51	Medium
SEP-6	0.53	Medium
SEP-8	0.56	Medium

Table 7. shows that every aspect of science and engineering practice has improved after using project-based learning modules. This is supported by several studies conducted by previous researchers. The research conducted by (Santoso, 2019) (Windriyana et al., 2019) explained that the application of project based learning could improve students' science and engineering practices in the aspects of planning and carrying out investigation and constructing explanations and designing solutions. project based learning can make the skills of students honed, especially those related to the psychomotor of students, this is making hypotheses, using tools to conduct experiments. The low skills of SEPs in the aspects of planning and carrying out investigations because students are getting lessons about SEPs for the first time (Amalia et al., 2020).

Research conducted by (Rachmawati et al., 2019) explains that real learning and practice can improve students' SEPs skills in the aspects of developing and using models. This also increases the concentration of students' practical skills. Based on this description, it can be concluded that the project-based learning module can improve the thinking skills of students.

CONCLUSION

The developed module is effectively applied in learning physics so that it can enhance the skills of SEPs. This is indicated by the gain value in each variable. The increase in SEPs skills is shown in the N-gain of 0.52. So it can be concluded that the effectiveness of the module is in the medium category.

SUGGESTION

Suggestions for further researchers can measure SEPs skills through learning models and other materials.

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