Advances in Social Science, Education and Humanities Research, volume 477
Proceedings of the International Conference on Community Development (ICCD 2020)

The Improvement of Higher-Order Thinking Skills Through Project-Based Learning on STEM Education Settings

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Abstract. **This study aims to determine the effect of applying the project-based learning in the STEM education setting to enhance students' higher-order thinking skills. The design used in this study is a non-equivalent (pretest-posttest) controlled group design. The population of this research is the 10th-grade students of Mathematics and Natural Sciences State High School in Yogyakarta, Indonesia. The research sample technique was an accidental sampling technique. The experimental group was guided to do project-based learning in the STEM education setting, while the controlled group was addressed to scientific learning. Two instruments used were multiple-choice questions to measure the higher-order thinking skills score, and questionnaires to collect the scientific attitudes data. The statistical analysis was d paired-sample T-Test. The learning effectiveness was interpreted from the N-Gain score. The result shows that there is a positive impact on the tudents' higher-order thinking skills. The other finding was that prior knowledge and scientific attitude contributed to increasing higher-order thinking skills. The impact of the finding is the possibility of this model contributing to physics learning, especially on the students' higher-order thinking skills.**

Keywords: project-based learning, STEM education, higher-order thinking skills, learning strategy, learning achievement

INTRODUCTION

A school is a place where formal education takes place and a place to get an education in various branches of science. Physics is one part of natural science, also known as science. Science is a process. It is a series of structured and systematic activities carried out to find concepts, principles, and laws about natural phenomena, including the ability to think to compile and discover new concepts. At present, science and technology are developing so rapidly that it has an impact on the development of learning methods and media in the world of education, especially in the development of teaching materials. Science learning with STEM education trains students to think critically, creatively, collaboratively, and communicatively [1]. Therefore, learning with STEM education supports the demands of education in facing the 21st-century and competency targets in the 2013 Curriculum.

The development of 21st-century education requires logical thinking, analytical, critical, and creative skills. These skills are essential for students to connect concepts and materials so that they can understand and solve problems in the class [2]. However, based on the results of a survey on the Trends in International Mathematics and Science Study (TIMSS) program, it shows that the average value of science achievement in Indonesia is below the international average. The average math score was on 38th, and the average score on science ranks 40th out of 42 countries with a total score of 386 and 406. The results are still below the average score of the standard amounting to 500 [3]. TIMSS questions are to measure the students' higher-order thinking skills. Students are still low in this skill [4].

The Program for International Student Assessment (PISA) in 2009 states Indonesia ranks 61, 57, and 60 out of 65 countries measured by the ability of students in the fields of Mathematics, reading, and science [5]-[7]. The National Center for Educational Statistics, publicizing the ability of Indonesian students, refers to the results of PISA in 2012. Most Indonesian students master subject matter up to level 4 only, while many other countries have reached level 5 and 6. MOEC stated that the level of understanding, depth, and the students' mastery in Indonesia is still limited compared to other countries in the Asian region. Most of the abilities mastered by the Indonesian students are at the level of doing with an average percentage of 5%. The learning process so far has not been able to explore the ability to think at a high level, including giving reasons with complete information, managing information, making generalizations, and presenting data [5].

STEM is a term used to collectively refer to interdisciplinary teaching and approaches, namely science, technology, engineering, and Mathematics. The integration of these STEM aspects can support the improvement of the students learning outcomes. The integration of STEM aspects can have a positive impact on student learning, especially in terms of increasing learning achievement in science

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and technology [8].

Governments, educators, business people, communities, and company leaders communicate the importance of STEM education and prepare students to be ready when in college and the real-work [9]. STEM education should [10].

(a) include the integration of technology and techniques into science and Mathematics;
(b) prioritize scientific inquiry and engineering design, including mathematics and science instruction;
(c) provide a collaborative approach to learning, connecting students and educators with STEM ;
(d) provide a global and multi-perspective perspective;
(e) combine strategies such as project-based learning, providing formal and informal learning experiences; and
(f) incorporate appropriate technology to enhance learning.

HOTS is a thinking process at a higher cognitive level. It is developed from various concepts, cognitive methods, and learning taxonomy, such as problem-solving, bloom taxonomy, and the taxonomy of learning, teaching, and assessment. The main objective of the HOTS is to improve the students' thinking skills at a higher level. It is especially related to the ability to think critically in receiving various types of information, think creatively in solving a problem using knowledge, and make decisions in complex situations [11]. Table 1 shows the concept of higher order thinking skills from many experts.

Research on STEM education learning towards HOTS is still rarely conducted. STEM learning scientifically can increase the students' interest in learning; it could make learning more meaningful to help students to solve real-life problems and support their future careers [12]. Besides, STEM provides challenges and motivates students because it trains students to think critically, to analyze, and to improve higher-order thinking skills [13]. Through STEM learning, students have scientific and technological literacy that appears in reading, writing, observing, and doing science. It can be used as provisions for social life and solving problems encountered in daily life related to the STEM science field [14]. Learning STEM is following 21st-century learning, which requires 4C (Critical Thinking, Creative, Collaborative, and Communicative) and fun for students. Students no longer view the learning process as an unpleasant form of compulsion [15].

Based on the previous learning definitions, this study aims to see the effect of STEM Project-based Learning. It is expected that from the research, this model will effectively increase the students' HOTS in accordance with the needs of the current era.

METHOD

This research was conducted with a pretest-posttest controlled group design. Two groups were applied to different learning schemes. One group was taught by using direct instruction learning, while the other was taught by using STEM Project-based learning. The independent variable of this study is the learning approach. The dependent variable is HOTS. These variable measurements are carried out using test questions in the form of multiple choice. This instrument has previously been tested for validity, reliability, level of difficulty, and power of determination.

The population of this research is the tenth-grade students of Natural Sciences in Yogyakarta in 2019/2020. The research sample was taken using a purposive sampling technique to obtain the experimental group and the controlled group. HOTS results were gathered from the pre-test and post-test, both in the form of multiple-choice questions. The data were analyzed using the T-test and N-Gain scores. The T-test is used to assess the effect of learning strategy on HOTS, including to determine the effectiveness of the N-Gain, homogeneity, and percentage of HOTS.

RESULT & DISCUSSION

The results of the research are the application of learning STEM PjBL on Newton's law material to increase HOTS. This type of research is a quasi-experimental method with a pretest-posttest controlled group design.

Descriptive analysis is performed to determine the amount of data, the average value, the maximum value, the minimum value, and the standard deviation. The statistical analysis obtained the average value of 33.13 for the experimental

Table 1: Basic Concepts of Higher Order Thinking Skills

Problem Solving from Krulik & Rudnick (1998)	Cognitive taxonomy of original Bloom (1956)	Bloom taxsonomy revised by Anderson & Krathwohl (2001)	Higher Order Thinking Skills (HOTS)
Recall	Knowledge	Remember	
Basic	Comprehense	Understand	
	Apllication	Apply	
Critical	Analysis	Analize	Critical Thinking
Creative	Syntesis	Evaluate	Creative Thinking
	Evaluation	Create	Problem Solving
			Decision Making

class' pre-test, test-while the post-test's average value was 80.00. On the other hand, the pre-test's average value for the controlled group was -34.41, while the post-test score was 64.56.

A normal distribution test is to determine whether the sample has a normal distribution or not. This test is performed on HOTS scores. The calculation of the normal distribution of scores was carried out using the Kolmogorov Smirnov and Shapiro-Wilk tests using SPSS 16.0. The data has a normal distribution if the significance (sig) produced is higher than the level of significance set at 0.05

Homogeneity calculation is applied to find out whether the data has homogeneous variance or not. Homogeneity calculation uses Levene's Test of Equally of Error Variance. The data has a homogeneous variance if the significance value obtained is higher than the level of significance set at 0.05.

By using the T-test on the post-test score, there is a significant difference between the average HOTS between the experimental group and the control group. The gain test is to see the effectiveness of learning.

The average pre-test and post-test results for the experimental group were 33.13 and 80.00, while for the controlled group was 34.41 and 64.56. The results of the analysis indicate that the experimental group's gain score is 0.698 with the medium category, while the controlled group gained 0.456 with the medium category. The test of this score shows that there is a difference between the two groups. It is concluded that the learning approach can increase the HOTS with the category of moderate improvement. While the other group also increases the HOTS with the same category. Therefore STEM Project-based learning is suitable to improve HOTS.

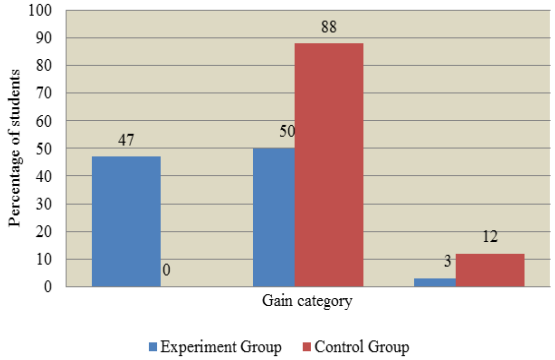

Figure 1. HOTS improvement

Figure 1 shows the amount of data from the experiment class as many as 32 students. It includes 15 students who achieved a high category (47%), 16 students achieved a moderate category (50%), and one student achieved a low category (3%). For the controlled group, there are 34 students. There are no students who have an increased HOTS in the high category (0%). Furthermore, 30 students got a moderate category (88%), and four students got a lower category (12%).

CONCLUSION

Based on the results of the research discussion and analysis on the application of STEM Project-based learning to enhance HOTS, it implies that this learning approach effectively increases the students' higher-order thinking skills.There are different HOTS scores between the experimental group and the controlled group. The N-gain categorization shows that this approach got medium category and suitable for improving HOTS. The current research has p roven to givecontribution to education, especially in physics learning. In addition, the learning model can be used as an alternative learning approach to increase (HOTS) in education.

ACKNOWLEDGMENT

Ministry of Education and Culture funded this research under the Postgraduate Research Grant for the Year 2020.

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