Connecting to 21st Century: Improve Students' HOTS through Integrated STEM Approach in Learning Physics

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Abstract: High order thinking skills (HOTS) of students has been a challenge in teaching and learning to prepare students to live in the 21st Century. This study attempted to investigate the effectiveness of an integrated STEM approach in enhancing students' HOTS in learning physics. This study used a quasi-experiment method with nonequivalent control group design. Total of the participants involved in this study were 66 students. The sample was taken by purposive sampling technique. The data were obtained from pre- and posttest result from 23 question in multiple-choice test of HOTS instrument. The Mann-Whitney test indicated that posttest of experimental and control group reported a significant difference in HOTS ($p<0,05$). The N-gain average in the experimental group was 0,41 with an intermediate category. The results of this study show that the students' HOTS can be improved by integrated STEM approach. These findings may be supporting the idea for a teacher in attempting to plan and provide appropriate strategies in teaching and learning to enhance their students' HOTS, specifically in physics.

1 INTRODUCTION

In the 21st century, which is characterized by the rapid development of science and technology, human resources with high competence are needed. These high competencies are creative thinking skills, critical thinking skills, and problem solving skills. These skills are categorized as High Order Thinking Skills (HOTS). HOTS is a thinking process, which consists of complicated procedures and needs to be based on various skills. HOTS refer to three highest domains of the revised Bloom Taxonomy (analyze, evaluate, and create).

Based on Programme for International Students Assessment (PISA), internationally comparable evidence on student performance that assesses how well students can extrapolate from what they have learned and can apply that knowledge in unfamiliar settings in the core school subjects of science, reading, and mathematics which is reported by the Organization for Economic Co-Operation and Development (OECD), HOTS of Indonesian students are still low. Indonesia in the 64th position from 72 countries. Indonesian students' score is 403 from 556, highest scores, in science.

Physics, a part of science, is tested in PISA. Physics is a difficult subject to understand by students. The students are unable to explain phenomena scientifically, to evaluate or design scientific investigations, and to interpret a data. One of the subjects in physics that requires HOTS is Newton's law concept. Newton's law is a basic science about the dynamics of motion which contains basic competencies that indicate activities that require HOTS process.

The low of student's HOTS has a negative impact on the students themselves if a solution is not found immediately. The impact such as the students are unable to apply the knowledge and skills they develop during learning in a new context and the students are unable to explain various natural phenomena and solve problems qualitatively or quantitatively. Moreover, if students do not have HOTS on Newton's law concept, the students will be difficult to learn physics concepts that use Newton's law as its basis, such as energy, impulse momentum, and rigid body.

The low of student's HOTS is caused by a learning process that does not encourage students to develop their HOTS. HOTS can be developed through a learning process that can stimulate students to practice their thinking skills. The process of learning that develops students' HOTS is learning process with student centered orientation, several

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scientific disciplines integration, and collaboration. The one of solution to develop students' HOTS is to use the integrated STEM (Science, Technology, Engineering, and Mathematics) approach during the learning process. Integrated STEM is a student centered learning approach. Integrated STEM is interdisciplinary approach to learning that removes the traditional barrier separating the four disciplines of science, technology, engineering, mathematics and integrates them into real world, rigorous, and relevant learning experiences for student.

Integrated STEM is an approach that provides great problem-solving opportunities for students in learning science, technology, engineering, and mathematics. Integrated STEM involves conditions that require the application of knowledge and practices from multiple STEM disciplines to learn about or solve problems. Problems that require an integrated STEM approach are typically ill structured, with multiple potential solutions, and require the application of knowledge and practices from multiple STEM disciplines.

In the class, the students are encouraged to make new and productive connections across two or more of the disciplines, which may be evidenced in improved student learning and transfer as well as interest and engagement. The students have opportunity to deepen their conceptual understanding while at the same time honing their skills by applying what they have learned in new contexts or in different settings. Previous studies showed that the integrated STEM approach has the potential to produce competitive human resources with the 21st century skills and positive impacts towards students' interest and achievement.

As mention above, there is a close association between HOTS and integrated STEM approach. A key point of this study is to attempt a strategy in learning to encourage students' HOTS. The purpose of the present study is to investigate the effectiveness of integrated STEM approach in enhancing students' HOTS in learning physics.

2 MATERIALS AND METHOD

2.1 Setting and Subjects

The study employed quasi-experiment method with nonequivalent control group design. The population consisted of 304 students at 10th grade in the SMAN 10 of South Tangerang. The sample size was consisted of 66 students, 33 students as participants in experimental class and 33 students as participants in control class. Purposive sampling was employed for selecting participants from among the students of the 10th grade in the academic years 2017-2018. All subjects were enrolled based on specific criteria.

In the experimental class, an integrated STEM approach was applied which involved students in 4 processes: scientific inquiry, mathematical thinking, technology literacy, and engineering design. In the scientific inquiry, students constructed their own knowledge through simple investigations. In the mathematical thinking, students applied the knowledge that gained during the scientific inquiry process to different situations and conditions in the form of problem solving or simple experimental projects. In the technology literacy, students used technology as a source of information and learning resources in the process of designing in engineering design. In the engineering design, students designed solutions to problems or design simple experiments. Meanwhile, in the control class applied a conventional approach.

2.2 Data Collection

The data collection tool was derived from objective test. The data were obtained from pre- and post-test result from 23 questions in multiple-choice test of HOTS instrument that consisted of C4 (analyze), C5 (evaluate), and C6 (create) cognitive domain in Bloom's Taxonomy. It was 9 questions of C4, 7 questions of C5, and 7 questions of C6. The minimum score is 0 and the maximum score is 23. The content validity of the test was authenticated by 14 experts from among the major members of Syarif Hidayatullah Islamic State University (expert in physics content, learning assessment, and Indonesian language). It was processed using content validity index (CVI) that interpret with content validity ratio (CVR). The result was valid. Whereas, the reliability was calculated using AnatesV4, which was 0.89 for the tool as a whole with high reliable criteria.

2.3 Data Analysis

After the data was collected through the research instruments tested, the data was processed and analyzed to answer the hypothesis. The data was submitted to SPSS 22. The data was analyzed descriptively and inferentially. Descriptively, the data was analyzed its frequency, percentage, mean, and standard deviation. Inferentially, the data was analyzed by Lavene to find out the homogeneity of the object, analyzed by Kolmogorov-Smirnov to find out the normality of sample distribution, and analyzed by Mann-Whitney U to test the hypothesis. The Mann-Whitney U test was used for variables with non-normal distribution and was used to investigate the effectiveness of integrated STEM approach to enhance students' HOTS. The N-gain test was used to see how the score, in each complex cognitive taxonomies, of experimental and control class increase.

3 RESULT AND DISCUSSION

The recapitulation of pretest, posttest, and N-gain data in the experimental and control class is presented in Table 1.

They are below half the ideal score (11.5 per 23). The pretest mean score of control class (7.39) was slightly higher than the pretest mean score of experimental class (6.67). There were a number of things that caused the low pretest score. The factor is the learning process did not encourage students to develop their HOTS. The learning process used teacher center oriented, monodisciplinary learning, non-collaborative learning, and it did not train students to solve a problem. It caused students' HOTS not developing well.

Table 1: The data of pretest, posttest, and N-gain score of students' HOTS.

Descriptive	Control		Experiment	
	Pretest	Posttest	Pretest	Posttest
Minimum Score	0.00	0.00	0.00	0.00
Maximum Score	23.00	23.00	23.00	23.00
Mean	7.39	9.73	6.67	13.45
Median	7.00	10.00	7.00	13.00
Mode	7.00	11.00	7.00	13.00
Standard Deviation	2.22	1.53	1.76	1.39
N-*gain*	0.13		0.41	
N-*gain* Criteria	Low		Medium	

The pretest score of both of classes were low. The final score (posttest) of students' HOTS of both of classes increased after different treatments was given. However, the increasing score of experimental class was higher than control class. The posttest mean score of experimental class was 13.45 and the posttest mean score of control class was 9.73. The improvement of students' HOTS could be seen from the N-gain score. The N-gain score for the experimental class was 0.41 (medium category) and the N-gain score for the control class was 0.13 (low category).

The higher posttest score of experimental class is caused by an integrated STEM approach that applied. These learning process involved real life situational tasks to be solved and the students were found to be able to address complex context in the tasks. Thus, learning process with integrated STEM provide experiences to identify the connections between what they have learned and new different things through high order thinking they used. It trained students' HOTS during the learning process.

The description of pretest, posttest, and N-gains score of students' HOTS at each level of complex cognitive (C4, C5, C6) in the experimental class and control class are presented in Table 2.

Table 2: Percentage of pretest, posttest, and N-gain score of students' HOTS in complex cognitive domain

Class	Score	C4	C5	C6
Control	Pretest	3.94	1.52	1.79
	Posttest	4.58	2.33	2.67
	N-gain	-0.02	0.13	0.18
	N-gain Criteria	*Low*	*Low*	*Low*
Experiment	Pretest	3.36	1.39	1.91
	Posttest	6.48	3.42	3.09
	N-gain	0.54	0.36	0.29
	N-gain Criteria	*Medium*	*Medium*	*Low*
Maximum score of pretest posstest		9.00	7.00	7.00

In the cognitive process, the pretest mean score of control class in C4 & C5 (3.94 & 1.52) were slightly higher than the pretest mean score of experimental class (C4=3.36; C5= 1.39). While, the pretest mean score of control class in C6 was 1.79, slightly lower than the pretest mean score of experimental class (1.91). Meanwhile, the posttest mean score of experimental class in complex cognitive process was higher than the posttest mean score of control class. It shows that, in the experimental class, there was a significant score increasing after was treated with an integrated STEM approach. The comparison of students' HOTS score in each complex cognitive domain (C4, C5, and C6) is presented in Figure 1.

In the Table 2, the improvement of students' HOTS based on cognitive processes in the experimental class which was treated with the integrated STEM approach was higher than the control class which was not treated with this treatment. The integrated STEM approach stimulated students to develop their HOTS during the learning process. Students analyzed a phenomenon related to Newton's law, evaluated a phenomenon that occurred around students, or planned a solution in solving a problem. Students did not only receive information or knowledge that was explained by the teacher.

The integrated STEM approach was interdisciplinary studies. It was more able to improve students' ability to identify problems and draw conclusions based on evidence in order to understand and make decisions. It trained students to work collaboratively, to engage students in problem solving, design, and assess an investigation, and to make learning activities more inquiry and contextual.

The comparison of the improvement based on cognitive processes obtained from the mean of N-gain score in each class. In the experimental class, C4 and C5 cognitive processes were categorized as medium category, while for C6 cognitive processes was categorized as low category. However, in the control class, each complex cognitive processes were categorized as low category. The good improvement of students' HOTS in experimental class indicated that integrated STEM approach was effective.

In the analyze process (C4), the students had to be able to separate information into several parts, find or describe relationships between information, and show the reasons or purpose behind the information. The improvement in C4 cognitive process was because the students concluded the relationship between variables based on some information obtained during the investigation on science process in integrated STEM approach.

In the evaluate process (C5), the students had to be able to judge a material or phenomenon based on specific criteria. The criteria used form of standards or criteria was made by students itself, but these criteria might be evidence and logic. The improvement in C5 cognitive process was because the students examined the simple experiments of each group that have been made taking into consider the suitability of the simple experiment with the concept of Newton's law.

In the create process (C6), the students had to be able to combine several ideas into a new one or arrange something have ever existed to be a new form by solving a problem with several solutions, make procedures to solve them, or make a new product. The improvement in C6 cognitive process was because the students made a solution of a problem that was presented then the students planned a simple experiment based on information or knowledge obtained in the scientific inquiry process. The assumption test results could be seen in Table 3.

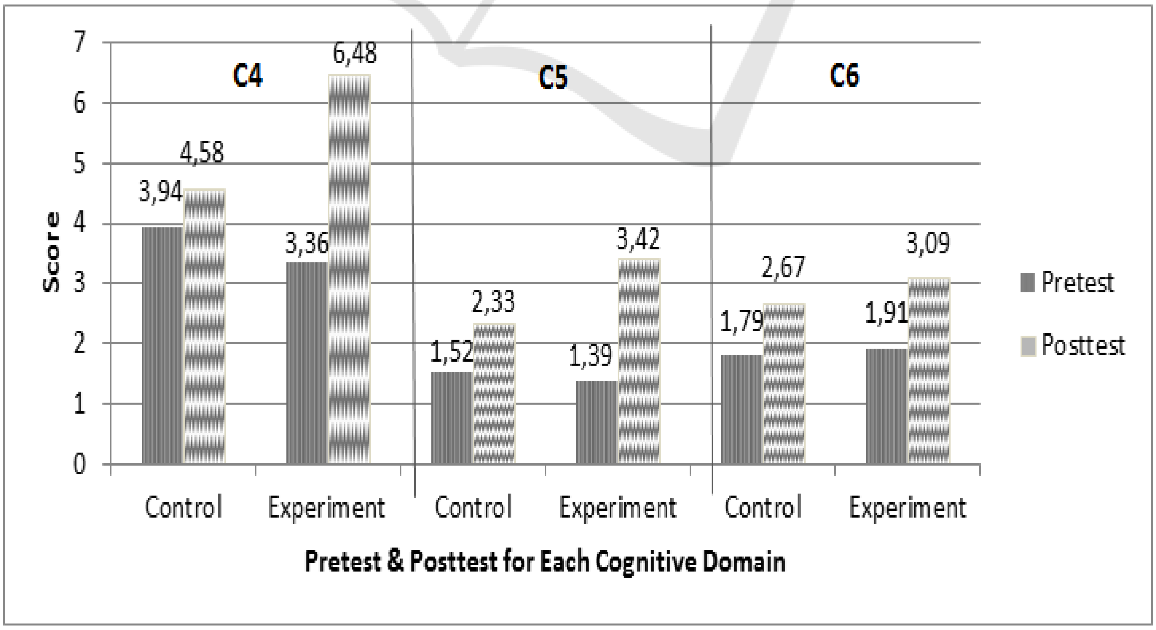

Figure 1: The comparison of students' HOTS score in complex cognitive domain

Table 3: The result of assumption test

Class		∝	Assumption test		Hypothesis test
			Normality	Homogeneity	
			Sig. Shapiro Wilk	Sig. Lavene	Sig. (2-tailed) Mann-Whitney U
Pretest	Control	0.05	0.000	0.21	0.140
	Experiment		0.000		
Posttest	Control		0.000	0.75	0.000
	Experiment		0.010		

4 CONCLUSION

This study found that using integrated STEM approach was effective to improve one capability needed in the 21st century (HOTS). HOTS of students who use this approach in learning increase by 0.41 (represented by N-gain score) as a medium category.

In each complex cognitive process, HOTS of students also increase. The experimental and control classes had the same N-gain category in C6 (create process), they were in low category.

However, in C4 (analyze process) and C5 (evaluate process) had different category. The experimental class was in the medium category and the second class was in the low category. Therefore, the results suggest that to improve HOTS of students in learning physics, it would be effective using integrated STEM approach.

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