



THE EFFECT OF THE STEM-PJBL MODEL ON THE HIGHER-ORDER THINKING SKILLS OF ELEMENTARY SCHOOL STUDENTS

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Abstract: The challenges of 21st-century education require higher-order thinking skills (HOTS) to exist in various fields. This study aims to determine the effect of the STEM-PjBL approach on HOTS. This research is a quasi-experimental study with the nonequivalent control group design model. The research data were obtained from 23 students of class IV A SD Muhammadiyah Macanan, Yogyakarta, as the experimental class, while the control class was 23 students from class IV B. The data collection technique used tests. The research instrument was in the form of multiple-choice test questions that had previously been validated by experts and empirical tests, which resulted in valid and reliable questions. The data analysis technique used an independent sample t-test and paired sample t-test. The results showed that the STEM-PjBL approach had a significant effect on student HOTS. There are differences in student HOTS before and after giving treatment. The differences in the HOTS' mean were also shown in the experimental class and the control class.

Keywords: STEM-PjBL; HOTS; elementary school students

INTRODUCTION

The rapid development of science and technology has implications for the advancement of the field of education. It is marked by changes in the curriculum that are adapted to market needs, namely the 2013 curriculum, which is designed to prepare students to become individuals who believe, are innovative, and can contribute to society (Fernandes, 2019; Sinambela, 2013). 21st-century education has challenges to building a knowledge-based society (Vali, 2013). A person's success in the 21st Century is not only determined by how broad his knowledge is but how to implement that knowledge to solve new problems collaboratively (Eng, 2013; Muhali, 2019). So, innovation is needed in curriculum adjustments adapted to the challenges of 21st-century education, namely 2013 curriculum (K-13).

In the implementation of K-13, the teacher acts as a facilitator. The teacher no longer acts as the only source of learning. It is intended to make learning more interactive. Students will do more physical and mental learning activities so that the whole learning process becomes student center learning. Teaching methods that were previously lectured must be replaced with more demanding models of student involvement in each process. The teacher's task as a facilitator for students is to facilitate learning in students so that students get an authentic learning experience. Teachers are expected to use models and approaches that can position students to be active, creative, and innovative in the learning process. All of these efforts are intended to equip students with higher-order thinking skills (HOTS).

HOTS is one of the variables that determine teaching and learning success, especially in higher education institutions. HOTS is part of the generic skills that must be empowered in all fields/lessons. Students with high HOTS can improve performance to reduce their weaknesses (Yee et al., 2011). HOTS can improve the quality of learning both in primary schools in higher education (Tyas & Naibaho, 2021). Contrary to this, the importance of HOTS for learning has not been matched by the high HOTS of students. Several studies show that the HOTS of elementary school students in Indonesia is still relatively low (Fanani & Kusmaharti, 2018; Ichsan et al., 2019; Khusnul Fajriyah, 2018).

Various studies have been carried out to improve students' HOTS, including learning models that empower aspects of HOTS. Eliyasni et al. (2019) found that the PjBL model with a blended learning approach could increase student HOTS but did not specifically explain the HOTS aspect. Rosidin et al. (2019) use the STEM model to improve students' thinking skills on analysis, evaluation, and creation indicators. In Rosidin's study, STEM was combined with HOTS-based assessment and stood as a learning model. However, the relationship between the model's syntax and the improvement of each indicator has not been explained yet. HOTS-oriented learning is expected to make students think so that teachers no longer play a full/dominant role in learning but rather empower all students' skills (facilitators) to make it easier for students to think (Tyas & Naibaho, 2021). Based on these findings, STEM can be combined with the PjBL model to produce a learning syntax that can empower HOTS aspects in students at each stage.

STEM learning emphasizes the integration of aspects of science, technology, engineering, and mathematics. The science aspect is represented in the activities of asking questions and developing explanations. The engineering aspect is represented in the activities of identifying problems and designing solutions. The mathematical aspect is represented by the activities of analyzing and interpreting data. In comparison, the technology aspect is represented by ICT activities and computational thinking (Maryani et al., 2019). The STEM approach is expected to provide meaningful learning for students (Ismayani, 2016). In addition, contextual learning through STEM

can bring learning materials closer to everyday life so that students understand more easily (Afriana et al., 2016; Permanasari, 2016). The benefits of the STEM approach include making students problem solvers, innovators, inventors, independent, and logical. Thus, teachers are advised to use STEM as a learning approach to achieve learning goals and improve technological literacy (Jaka Afriana et al., 2016; Iolanessa et al., 2020). The STEM approach does not have steps or procedures to be applied in learning, so it requires learning methods to run it, one of which is the Project-Based Learning (PjBL) method.

PjBL is a model that is identical to PBL but emphasizes projects as a way of solving problems. Students explore, evaluate, interpret, synthesize, and provide information to produce various learning outcomes (Ambarwati et al., 2015). In this learning model, students are empowered to create a project due to learning by using the potential possessed by students. The project in question consists of complex tasks based on previously identified problems. In this model, the activities carried out by students are: designing, solving problems, making decisions, working autonomously with calculated time, and at the end of the lesson producing realistic products and presentations. PjBL can teach students to gain new knowledge and experience based on experience in solving problems in the project. PjBL is a student-centered learning model. Learning activities are no longer dominant to the teacher but are more dominated by student activities (Wulandari, 2016). In PjBL, the teacher designs complex problems and directs students to solve them using projects according to the teacher's instructions. Wahyuni (2019) stated the PjBL aims to activate students; make learning more interesting and interactive; improve understanding and problem-solving skills, critical thinking, collaboration, and communication skills; & increase learning motivation, students' responsibility, and management skills.

The results of observations in several elementary schools in Yogyakarta, Indonesia, in 2019, found various problems experienced by students, including teachers who had not fully empowered or trained students' HOTS during learning. It can be seen from the learning method used by the teacher, which is still in the same direction. Most still use the lecture method and one-way discussion so that students do not try to get information independently. The results in HOTS students being less trained. Nahdi (2017) stated conventional learning does not increase HOTS because students' thinking skills are not optimized through learning experiences.

The next problem is that students have not maximized higher-order thinking skills in responding to a problem. In teaching and learning activities, students still ask for the help of their friends to express their opinions. Students are still not too active in responding and providing answers to problems. A teacher should pay attention to students' cognitive development to practice problem-solving skills and students' mathematical critical thinking (Noordiana, 2018).

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The description above illustrates that HOTS can be trained with a learning model that involves students' thinking processes, including analyzing, synthesizing, or connecting facts and ideas to solve problems. The STEM-PjBL approach was chosen in this study because, in every step, all student activities can be maximized. The STEM-PjBL model in this study emphasizes the process of designing an experiment as a way of finding solutions to problems. Each stage in the design process is directed at empowering students' thinking processes and simultaneously involves cognitive, affective, and psychomotor aspects.

METHOD

Research Methods

This research is a quasi-experimental study with a nonequivalent control group design. Students from SD Muhammadiyah Macanan, Yogyakarta became the research location. The time of the study was carried out in August-December 2019. In the research design used by this author, before being given treatment, students were given a pretest to measure the initial ability (HOTS). After treatment, students were given a post-test to determine HOTS after being given action. It applies to the experimental class and the control class. Treatment is given in five meetings for each class, as shown in Table 1.

Population and Sample

In this study, the population was taken from all 4th-grade students of SD Muhammadiyah Macanan Special Region of Yogyakarta, namely grades 4A, 4B, and 4C. This study used two classes

as samples taken randomly. Class IV-A, which consisted of 23 students, was used as the experimental class, while Class IV-B also had 23 students functioning as the control class.

Table 1. Learning Activities in Experiment Class and Control Class

Meeting	Experiment class	Control class
1.	Pre-test	Pre-test
2.	Submission information and discussion of the study material, preparing the equipment to be brought and the division of tasks in the context of project implementation	Discussion and presentation of material from the teacher then continued discussion
3.	Students carry out the project together with a group of friends while the teacher monitors the implementation of the project	Students are asked to pay attention to the teacher's explanation when explaining the learning material
4.	Students present the results of working on projects in groups and conclude the learning materials together. Other students evaluate the results of the presentation.	Students work on the questions given by the teacher as an exercise
5.	Post-test	Post-test

Data Collection Techniques and Instruments

The data collection technique used a test of higher-order thinking skills with essay questions. There are 30 test questions representing aspects of analysis, evaluation, and creation. Before being used, the questions were validated first by content on the instrument expert. After being revised based on expert input, the instrument was then empirically validated on students. It produced 30 valid questions with $R_{\text{count}} > 0,268$ while reliability was calculated using Cronbach's Alpha with R_{count} of 0.821, which means high reliability.

Data Analysis Technique

Data were analyzed using descriptive statistics and inferential statistics. Descriptive statistics are used to determine the data description of higher-order thinking skills. Inferential statistics test the hypothesis by using a t-test, namely paired sample t-test and independent sample t-test. Paired sample t-test was used to determine the difference in HOTS before and after treatment. In contrast, the independent sample t-test was used to determine the difference in the mean HOTS of the control class and the experimental class.

RESULT AND DISCUSSION

Learning with the STEM-PjBL model in this study consisted of several stages. STEM as an approach contributes components of science, technology, engineering, and mathematics in an integrated manner in project themes. Meanwhile, PjBL contributed a syntax consisting of 1) start with the essential question, 2) design a plan for the project, 3) create a schedule, 4) monitor the students and the progress of the project, 5) assess the outcome, and 6) evaluate the experience (George Lucas, 2007).

The theme of this research is the theme of “Selalu Berhemat Energi” in the sub-theme of “Manfaat Energi.” The essential question given is the problem of limited energy sources in the environment. Students are given contextual problems so that they can be discussed in groups how to solve them. At this stage, the analytical aspects of HOTS are trained in the process of finding solutions. The teacher guides the discussion process to find this solution through a stimulus in information about the availability of used goods around the school environment. Students then come up with ideas to process them into alternative energy sources or their tools. One of the works produced by students is a water/windmill, which includes all aspects of STEM. At this stage, the HOTS aspect of creation is trained when students design and make waterwheel or windmill.

During the process of doing works, students are guided by a worksheet. The teacher is in charge of guiding and directing students to have group discussions—the teacher is a facilitator who pays attention to students and provides guidance to groups experiencing difficulties. Next, the teacher assigns each group to present the discussion results for other groups to respond. After presentations between groups, students and teachers conclude the results of the discussions conducted so that the perceptions between students are the same. The presentation aims to train students to be actively involved in a discussion not only as recipients of information but also to express their personal opinions. HOTS in the evaluation aspect is trained at this stage (Chun & Abdullah, 2019). It is because students share ideas to solve a problem given by the teacher to be able to achieve the desired goal. In group learning, students will be fully involved, and learning becomes more fun because students feel challenged to be able to complete a project (Maryani et al., 2020).

Students’ HOTS was measured before and after treatment using multiple-choice questions at the cognitive level of analysis, evaluation, and creation, as written in Table 2.

Tabel 2. HOTS Pre-test and Post-test Questions

Indicator	Sub Indicator	Question Number
Analyze	Categorizing	1,4, & 6
	Differentiating	9
	Organizing	8
Evaluating	Measuring	7 & 11
	Considering	14
Create	Composing	12
	Designing	2, 5, & 15
	Formulating	3, 10, & 13

HOTS pretest and post-test data were taken in both groups using the same instrument. The description data can be seen in Table 3.

Based on Table 3, the pretest of the control and experimental classes were not significantly different, but they both showed a significant difference at the time of the post-test. It can be proven in hypothesis testing through different tests. Hypothesis testing using the t-test must meet the

assumptions; namely, the data must be normal and homogeneous. Therefore, a normality test was carried out with the one-sample Kolmogorov-Smirnov Test, the results shown in Table 4.

Table 3. Description of HOTS Pre-test and Post-test Data

	N	Max	Min	Sum	Mean	Std. Deviation	Variance
Model	46	1.00	2.00	69.00	1.5000	.50553	.256
Pretest	46	.00	100.00	3061.00	66.5453	25.13670	631.854
Posttest	46	27.00	100.00	3646.00	79.2609	20.70366	428.642
Valid N	46						

Table 4. Normality Test Results with One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residual
N		46
Normal Parameters ^{a,b}	Mean	.0000000
	Std. Deviation	.46795987
Most Extreme Differences	Absolute	.248
	Positive	.162
	Negative	-.248
Test Statistic		.248
Asymp. Sig. (2-tailed)		.000 ^c

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

Table 5. Homogeneity Test Results

Variable	Levene Statistic	Sig	Information
Pretest of experimental-control class	1.623	0.209	Homogeneous
Posttest experimental-control class	0.130	0.720	Homogeneous

Based on Table 4, it is stated that the data is normally distributed. The next stage is to do a homogeneity test which aims to test the similarity of the data between groups. A homogeneity test was carried out using SPSS with the Levene formula. Data is said to be homogeneous if sig is greater than alpha (0.05). The results of the homogeneity test are shown in Table 5.

Table 5 shows that the experimental and control class's sig value is 0.720 (> 0.05). The value shows that the data is homogeneous or comes from a population with the same variance. Then it can be continued by using parametric statistics, namely the t-test. The t-test was used to explain the effect of using the STEM-PjBL approach on the HOTS of fourth-graders at SD Muhammadiyah Macanan.

The t-test aims to determine whether or not there is a difference in HOTS in the experimental class and the control class. The paired sample t-test was conducted to determine the difference between the pretest and post-test mean in the experimental class. In contrast, the independent sample t-test was used to test the difference in the post-test mean in the experimental class. The results of the analysis were compared with $= 0.05$. If the value of sig > 0.05 means that H_a is rejected, otherwise, H_a is accepted. The results of the Paired Sample t-test analysis can be seen in Table 6.

Table 6. Paired Sample t-Test Analysis Results

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-test	66.5435	46	25.13670	3.70620
	Post-test	79.2609	46	20.70366	3.05259

Table 7. Results of Descriptive Analysis of Post-test Data

Group Statistics					
	Method	N	Mean	Std. Deviation	Std. Error Mean
Post-test	Experiment	23	86.3478	16.73757	3.49002
	Control	23	72.1739	22.17216	4.62322

Table 6 shows the results of the descriptive statistics of the two groups. The mean of the HOTS pretest was 66.5435, while the mean of the HOTS post-test was 79.2609 for both groups. The correlation test results with paired samples correlations show the magnitude of the correlation value of 0.858 with sig 0.000 (< 0.05). It shows that there is a significant relationship between pretest and post-test. Next is a hypothesis test that refers to the following statistical hypothesis:

H_0 : there is no difference in the mean of HOTS pretest and post-test, which means there is no effect of the STEM-PjBL approach in increasing students' HOTS.

H_a : there is a difference in the mean of HOTS pretest and post-test, which means there is an effect of the STEM-PjBL approach in increasing students' HOTS.

The results of hypothesis testing shows that the sig value is 0.000 (< 0.05), so that it is stated that H_0 is rejected, which means that there is a difference in the average HOTS pretest of the control class and the experimental class. It shows that there is an effect of the STEM-PjBL approach in increasing students' HOTS. In addition, the study also succeeded in analyzing the difference in the post-test mean of the experimental and control classes. The results can be seen in Table 7.

Sig. on Levene's test for equality of variance is 0.209 (> 0.05), which means that the experimental and control class data variances are homogeneous or the same. Then seen from the t-test for equity of means, the value of sig (2-tailed) is 0.018 (0.05), which means H_0 is rejected or H_a is accepted. Thus, it can be concluded that there is a significant difference between the mean HOTS of students in the experimental class and the control class. It shows that the STEM-PjBL approach affects students' HOTS. Furthermore, based on the mean difference of 14,17391, the difference in the average HOTS of the experimental and control classes. Based on the data, it can be concluded that the HOTS in the experimental class is significantly different from the HOTS in the control class.

Based on the hypothesis test, it was stated that the mean of HOTS in the STEM-PjBL class was significantly different from the lecture class. It is consistent with the results of previous studies, which state that both STEM and project-based learning approaches can positively impact student activity and involvement in the learning process. Ntemngwa & Oliver (2018) found that using the STEM approach can help students solve problems by applying aspects of science, technology,

engineering, and mathematics. However, the study did not explicitly find a relationship between STEM and students' analytical, evaluation, and creative abilities. Febrianto et al. (2021) also stated that STEM-PBL could improve critical thinking skills. However, this study does not directly state the effect of this model on higher-order thinking skills (HOTS).

HOTS includes several abilities, namely: critical thinking, logical, reflective, metacognitive, and creative (Kuiper & Pesut, 2004; Retnawati et al., 2018). HOTS are needed to solve problems and make decisions. HOTS can develop if students discover new things that they rarely encounter or in challenging circumstances. With the challenges given to students in the form of projects by the teacher, students should perform various thinking skills that lead to higher-order thinking skills.

The HOTS of class IV-A students as an experimental class in completing a project is in the very good category, 69.60 %. The STEM-PjBL approach involves various aspects or abilities to complete a project to achieve the expected goals. Thus, the learning carried out by students becomes more meaningful because students are actively involved in project completion. It should train students' creative abilities by manufacturing products carried out in the project (Genc, 2014). This finding may be caused by other factors that come from within students and external factors such as the teacher's role in guiding students during the STEM-PjBL learning process.

The STEM learning approach can improve students' abilities in cognitive and psychomotor aspects (Sumarni et al., 2019). Students' cognitive abilities become honed because, in the learning process, students must be actively involved in problem-solving. This STEM-PjBL approach also improves student skills which can be seen during the project work process. It can develop students' new ideas and knowledge in solving a problem. Increasing students' higher-order thinking skills in solving a problem can provide experiences and challenges for students and can provide student learning motivation. The more often students are actively involved in a problem-solving process, the students will become accustomed to solving various problems they face in the real world. So that students' higher-order thinking skills will also increase according to the organizational processes experienced.

This study succeeded in finding that the STEM-PjBL approach affected students' higher-order thinking skills. The STEM-PjBL approach provides opportunities for students to be actively involved in completing projects. In this approach, STEM-PjBL learning is carried out in groups to give students the freedom to express their opinions with their group mates. So that automatically, students will actively discuss to find new information through the given project. Students' higher-order thinking skills influence the discussion process to complete the project given by the teacher and achieve the expected goals.

PjBL-STEM is implemented by prioritizing active student involvement, characterized by constructive inquiry, collaborative, communicative, autonomy of student, reflective, and goal setting

in real-world situation (Kokotsaki et al., 2016). STEM-PjBL in this study makes students collaboratively work in each group to solve authentic problems, frequently challenging for students, based on curriculum, and interdisciplinary (STEM). Students can see the problem from their point of view, and decide how and what to do to solve the problem. They collect a variety of information from a variety of sources. Furthermore, students will analyze, synthesize, and gain new insights through this process. Meaningful learning occurs in students' learning experiences because there is collaboration and reflection between real life and problems that are used as an introduction for them to learn with the help of adults (teachers) (Efstratia, 2014). At the end of this process, students can demonstrate their newly acquired knowledge, review how much they have learned, and how well they communicated it. Throughout this process, the teacher's role is to guide and direct.

CONCLUSION AND SUGGESTION

Conclusion

The STEM-PjBL approach affects students' higher-order thinking skills. The independent sample t-test analysis results in the post-test experimental class and control class, showing that the t value is 0.115 and the significance value is 0.036 ($\text{sig} < 0.05$), which indicates that there is a difference in the post-test mean of students treated with the STEM-PjBL approach. And conventional. The increase in the pretest - post-test mean of the experimental class, was also higher than the control class. The PjBL syntax in this approach can increase students' creativity, and students can be actively involved in the learning process. Thus, learning becomes more meaningful, and students gain new experiences in solving a problem. Students' ability to answer questions is better than before the STEM-PjBL learning treatment. Students can gain new knowledge, answer questions according to the correct context, solve complex problems, and make the right decisions. In addition, students become more active in participating in learning because they have to complete a given project.

Suggestion

By the research' result, while implementing the STEM-PjBL approach, teachers should use devices arranged based on STEM-PjBL. It will make student learning experience can be supported with teaching materials and learning resources that follow the needs of STEM-PjBL.

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