JIPI (Jurnal IPA dan Pembelajaran IPA) 7(2), p.166-176, (2023)
p_ISSN: 2614-0500 e_ISSN: 2620-553X
URL: http://jurnal.usk.ac.id/JIPI/index DOI: dx.doi.org/**10.24815/jipi.v7i2.30196**

The Effect of the Problem Based Learning using STEM Approach on Higher Order Thinking Skills and Learning Activities in Junior High School Students

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Article History:
Received date: January 10, 2023
Received in revised from: May 12, 2023
Accepted date: May 24, 2023
Available online: June 13, 2023

Citation:
Wahyuningtyas, A.D., Putra, P.D.A., & Nuha, U. 2023. The effect of the problem based learning using STEM approach on higher order thinking skills and learning activities in Junior High School students. *JIPI (Jurnal IPA dan Pembelajaran IPA)*, 7(2):166-176.

Abstract. Higher-order thinking skills (HOTS) are one of the skills that must be possessed by students in facing the demands of the 21st century. However, Indonesian students' HOTS currently tends to be low. The purpose of this study was to determine the effect of the PBL using STEM approach on students' HOTS and learning activities. The sample of this study was 48 Junior High students who separated in two clases (experiment and control group). All the students were of 8th grade in SMPN 2 Ajung with a non-equivalent control group design. HOTS data was obtained by giving a pretest and posttest with 10 multiple choice questions. Furthermore, the learning activities was observed via activies observation protocol during the learning process. The application of the PBL using STEM approach was quite effective in the experimental class with a posttest average of 85. This was confirmed by the paired sample test of $0.001 < 0.05$ which could be concluded that the PBL uisng STEM approach had a significant effect on HOTS and learning activities. This finding is an alternative integrative model innovation between PBL and STEM based on students' skill levels.
Keywords: stem, HOTS, PBL, dan Students' Learning Activities

Introduction

Global competition and technological developments in the 21st century are marked by advances in technology, information, and communication. The era commonly is known as the digital era. Education plays a very important role in running future Indonesian generations. They must have life skills to face future challenges (Kim et al., 2019). Learning in the context of 21st century is a learning demand, especially in the "*Merdeka curriculum*" in which students have an opportunity to learn a subject through an example, application, and experience in the real world both inside and outside of school (Sulaeman et al., 2022). One effort to improve the quality of human resources can be done through by science education (Huang et al., 2022). Suwarma & Apriyani (2022) proved that the main goal of science education was to help students to optimize higher-order thinking skills (HOTS) and to prepare students to face future challenges.

However, the teaching process in the school, especially in science education, still tends to be teacher center (Fatimatuzzohrah et al., 2020). This learning process causes that students have low HOTS. This results also was related to students' critical and creative thinking skills that are not develop (Putra et al., 2021). Furthermore, when teacher only focuses to deliver a science content material in the classroom, students' activities in the clasroom also do not improve (Putra & Kumano, 2018). Theacher should improve the stuendent's HOTS mainly in the science clsroom because HOTS has a crusial role to develop the science concept in related with the real-world phenomenon (Rizkika et al., 2022). The lack of a designed learning approach in a science clasroom to use higher-order thinking skills also causes students to have low level of HOTS (Hikmah & Amin, 2019).

One of the strategies that can be carried out in developing HOTS is by applying a learning model in science classroom. The learning model can facilitate the stuents to involve being active and solve the real-world problem (Hasanah et al., 2022). Fanani (2018) explanes that learning in classroom to train higher-order thinking skills can be conducted through a problem-based learning (PBL) model. Through that lerning model, students have the ability to think at a high level, then the learning process also forms a space that students can find the activity-based knowledge concepts to solve problems (Kusumawardani et al., 2023). In line with Pratiei (2019) explaine that the improving of higher-order thinking skills can be used by applying active learning model, in which is student-centered and referred to constructivism.

The application of innovative learning is needed in learning strategies as an effort to improve the learning paradigm towards the demands of 21st century skills (Meilani et al., 2020). One learning model that is thought to be capable of positioning students as the focus of learning is the PBL. This learning model is oriented towards student centered learning (Fidan & Tuncel, 2019). Applying the PBL model requires specific teacher skills in science learning. Teachers bring natural phenomena into a problem aimed to the students (Ortmann & Roehrig, 2019). Therefore, science learning requires a learning approach that emphasizes student experiences and problems in accordance with the real world (Putra et al., 2021). One of the learning approach is the science, engineering, technology, and mathematics (STEM) learning approach (Wieselmann et al., 2020) .

The STEM approach is a learning approach that integrates multidiscipline so that it is able to solve problems of scientific phenomena in all aspects of life (Putra & Sulaeman, 2021). Through this approach students are expected to be able to explore problems in everyday life in the context of real problems (Margot & Kettler, 2019). PBL learning with the STEM approach makes learning centered on students to provide direct experience (Fidan & Tuncel, 2019). In addition, PBL learning with the STEM approach is a learning model that confronts problems in the context of science, technology, and mathematics to find new experiences by linking issues and problems in the surrounding environment that are closely related to science (Widowati et al., 2021).

PBL with the STEM approach is a learning model that is thought to be capable of being an alternative in solving problems in science learning in the form of low higher order thinking skills and learning activities (Triani et al., 2022). The PBL model with the STEM approach is believed to be able to overcome these problems because this model is based on the process of solving problems with natural science fenomenon based on facts by using the integration of various fields of science (Kloser et al., 2018). In addition, the implementation of PBL with the STEM approach emphasizes giving students experience to carry out activities to solve scientific problems (Putra et al., 2023). The research purpose in this study was to investigare the influence of the PBL with the STEM approche toward the junior high school stuedents' HOTs and students' activities in learning science.

Methods

This study used a quasi-experimental method with a non-equivalent control group design. This design used two classes, namely the experimental class and the control class through random sampling. The two groups were given tests in the form of pretest and posttest. The pretest questions were given at the beginning of learning which purposed to measure students' initial skills and knowledge while the posttest questions were given after the class was given treatment. The posttets was intended to measure students' final skills after implementing learning activities. The research design is described in Table 1.

Table 1. Research Design

Group of Class	Pretest	Threatment	Posttest
Experiment Class	P	✓	Q
Control Class	P	X	Q

Keterangan:
P = pretest in experiment and control class
✓ = Threatment of the PBL using STEM approach
X = without the threatment
Q = posttest in control class

The population in this study were students at one of the public junior high schools in Jember district class VII for the 2022/2023 academic year, with a total of 108 students. Random sampling technique is a technique used to collect data, in which subjects are taken from the population randomly without regard to whatever dominates. After the pretest asd conducted to the students in 4 classes, the control class and experimental class could be determined. The experimental class was 8^{th}- A, and the control was 8^{th}-C. The number of students from each class was 24 students. The demographics of the experimental class and the control class in this study are presented in Table 2.

Table 2. Class demogration between experiment class and control

Class	N Students		N total Students
	Female	Male	
Experiment Class	11	13	24
Control Class	9	15	24

HOTS data accumulation of students was carried out by using an objective test in the form of multiple-choice questions with a total of 10 questions with HOTS indicator domains. The indicators developed follow the cognitive domain of Bloom's taxonomy Revised by Anderson & Sosniak (1994) which is including analysis skills, evaluation skills, and creative skills. While student learning activities are carried out by observing student activities during learning activities both in the control and experimental classes. Student learning activity instruments are developed by emphasizing activities about: doing assignments, discussing, describing problems, asking questions, responding, paying attention to the teacher.

The pre-test questions were given before learning begins or before the treatment which was useful for understanding students' initial HOTS abilities. In the end of treatment, the posttest was carried out to evaluate the students' HOT. After the data was collected, a hypothesis test was carried out using the SPSS Version 26 program. The value obtained from SPSS was then tested by the right-sided t-test to show which average score was better between the experimental and control classes.

Ha1 = There are significant differences in the HOTS of students in the experimental class and the control class.

The HOTS measurement analysis in this study used the HOTS indicator developed by (Purbaningrum, 2017). The results of the scores obtained by students were grouped into 5 categories ranging from very poor to very good. The HOTS' categories were described in Table 3.

Table 3. HOTS' Categories

Score	The ability of Students' HOTS Categories
81 - 100	Verry good
61 - 80	Good
41 - 60	Medium
21 - 40	Weak
<20	Very Weak

Analysis of student learning activities was based on learning activities that had been carried out in research for 2 weeks. In this study, student learning activities were analyzed using observation sheets with indicators to be observed and assessed with certain formulas and certain percentages. To determine the influence of learning activities in the experimental class and the control class could be evaluated by comparing the final percentage results of the two classes. The following was an observation sheet that was used as a guide for observing student learning activities could be listed in Table 4.

Table 4. Criteria of Students' Activity

Grade of Students' Activity	Criteria
$80< X \leq 100$	Verry Good
$60 < X \leq 80$	Good
$40 < X \leq 60$	Medium
$20 < X \leq 40$	Weak
$0 < X \leq 20$	Very Weak

Results and Discussion

The science teaching implemented the PBL using the STEM approach, which was a learning process that created and encouraged students to actively analyze, evaluate, create, and draw appropriate conclusions in solving predetermined problems. PBL with STEM approach supported students in improving their thinking skills and developing student skills (Fidan & Tuncel, 2019). In this study, learning activities had been carried out through the use of the PBL with the STEM approach. This research activity was carried out for two weeks. Each week, 160 minutes of learning was carried out. Learning focuses on heat material and its transfer. Learning was assisted by completing student worksheets (LKPD) and practicum activities. The assessment was carried out to find out the students' HOTS and observations through the use of implementation observation sheets in knowing the activities carried out by students during the learning process. Data regarding HOTS on heat and transfer material using the PBL model with the STEM approach were obtained with pretest and posttest scores. The HOTS pretest and posttest results of the students that were obtained in this study are presented in Table 5.

Table 5. The Result of pretest and posttest HOTS

	Pretest		Posttest	
	Experiment	Control	Experiment	Control
N of Students	24		24	
Max	60	50	100	90
Min	25	10	75	65
Avarage	32,29	28,95	85	78
SD	12,52	12,42	7,25	6,55
Homogeinity	.287	.287	.287	.287
Normality	.200	.200	.083	.052
Independent sample t-test	.359		.001*	

*significant at $\alpha = 0.05$

Table 5 showed that the average value of the posttest discribed a significant difference between the acquisition of the control class and the experimental class based on the difference in value. Especially, the experimental class was 85 and the control class was 78. In the acquisition of the average pretest value, the experimental and control classes do not have significant variations. The significance of this statement was based on the difference in value, namely in the experimental class, namely 32.29 and in the control class, 28.95. In the results, the average posttest scores for the experimental class and the control class had a significant average difference, namely the experimental class was 85, while the control class was 78. The average pretest scores of students in the experimental class had sufficient HOTS abilities, while the control class had less HOTS abilities. In the experimental class, the highest pretest value was 60 and the lowest score was 15, while the highest posttest score was 100 and the lowest score was 85. In the control class, the highest pretest score was 50 and, the lowest score was 10 and the highest posttest score was 90 and the lowest score was 65. Learning using PBL with a STEM approach has a greater value than the control class.

The results obtained from the homogeneity test are 0.287, which means the significance value of the results of the daily test scores for the experimental class and the control class is greater than 0.05 (0.287 > 0.05). Guided when the significance value is greater than 0.05, it proves that the results of the previous daily test scores of the two classes are homogeneous. Then the previous daily test value data meets the requirements for parametric statistical tests. Meanwhile, the results of the normality test indicated that the pretest significance value for both the experimental and control classes had a significant value of 0.200. Meanwhile, the posttest data for the experimental class and the control class respectively had a significance value of 0.083 and 0.052. Judging from the basis of decision making, the data normality test will be normally distributed when the significance value is more than 0.05. In this case the pretest and posttest results of the experimental class or control class are normally distributed data.

Through the results of the independent sample t-test the pretest data showed no significant difference and the posttest found a significant difference in the mean HOTS increase of students in the experimental class and the control class. Judging from the results of the pretest test for the experimental and control classes, it showed a significant value of 0.359 > 0.05, so it can be concluded that Ho was rejected and Ha was accepted so that it can be seen that there is a clear difference in the mean HOTS score between the experimental class and the control class. Whereas from the results of the posttest test in the experimental class with the control class it showed a significant value of 0.001 < 0.05, so that it could be concluded that Ho was accepted and Ha was rejected so that it could be concluded that there was a significant difference in the mean HOTS score results between the experimental class and the control class. This difference can be seen due to the reason that PBL learning with the STEM approach encourages students to always think highly in finding concepts and linking through experiences that students have with the material being studied, this is in accordance with research conducted by (Nurazmi & Bancong, 2021). Learning using PBL with the STEM approach is a learning pattern based on the philosophy that students are able to receive instruction if students can grasp an understanding of the material in depth and then associate it with some new information and knowledge, they already have (Lee et al., 2019). Decision making was conducted after analyzing and evaluating what they understand (Putra et al., 2021). In line with opinion by Owens & Hite (2020) which states that using the PBL model with the STEM approach students can play an active role optimally in learning activities, such as exploring and solving problems, besides that students solve problems that must be solved by linking scientific knowledge with the use of technology, engineering, and mathematics.

PBL learning with the STEM approach facilitates students to develop HOTS skills because students are always required to think at a higher level in developing problem solving concepts. Maulidia et al. (2019) stated that the use of the STEM approach in PBL learning was able to improve physics learning outcomes, especially in creative thinking skills. The learning process with PBL through the STEM approach is also able to stimulate and motivate students to think at a higher level and make it easier to understand theories and concepts as well as meaningfully understand previously mastered knowledge, this is in line with research (Widowati et al., 2021).

Learning activities are a series of activities or activities that are consciously carried out by students which result in changes in themselves, in the form of changes in knowledge or skills that need to be considered by the teacher (Besare, 2020). Learning activities themselves can be honed by applying a teaching and learning design, student learning activities will be far more effective in receiving the knowledge or skills to be acquired (Dahlan et al., 2023). In this study the indicators of learning activity that were measured were understanding the topic, describing problems, discussing, asking questions, responding, and teamwork (see in Figure 1).

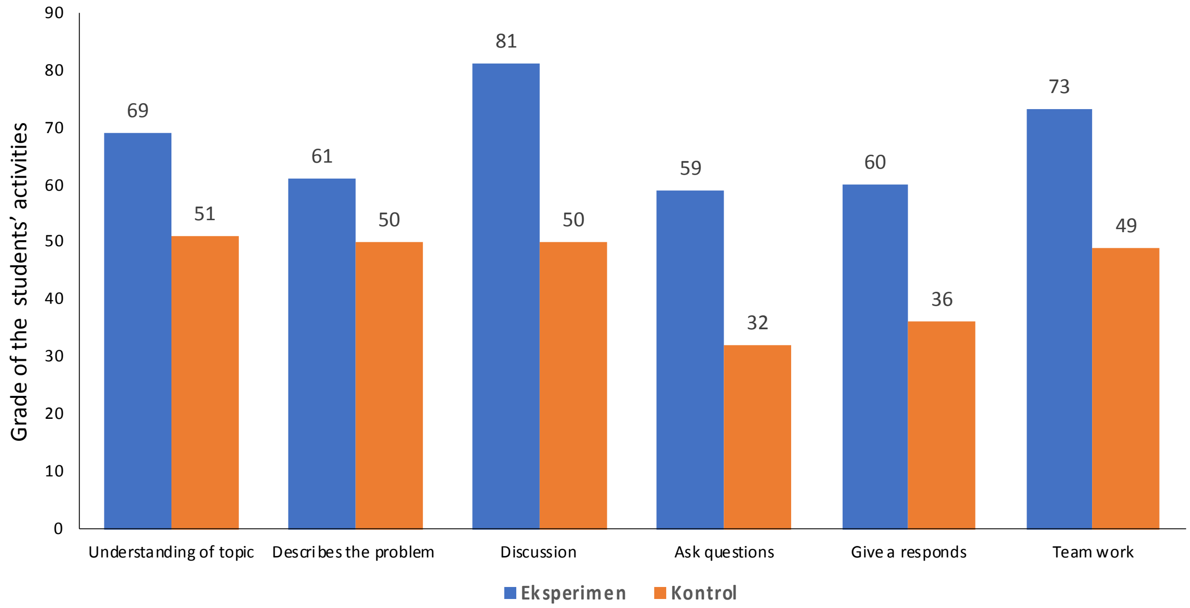

Figure 1. The grade of comparation student's activities

From the data above, it can be concluded that the percentage results for the six indicators in the control class are lower than the experimental class. The highest acquisition is discussion and group. When discussing students are more enthusiastic, help each other, and exchange opinions. In terms of groups students are also more enthusiastic and help each other in practicum. The application of the PBL model with the STEM approach in learning activities, students play an active role in learning activities because the learning that is carried out is related to problems by designing practicum tools according to their creations. Students can explore these problems starting from analyzing, evaluating, and creating. So this is the same as the HOTS indicator where the PBL model prioritizes the active role of students. Meanwhile, the STEM approach encourages students to play an active role in solving problems that are taken directly from real problems. So, when the PBL model is integrated with the STEM approach it will greatly impact student HOTS. This is relevant to research Tamaela et al. (2021) who states that the PBL model with a STEM approach is effective in training students' higher-order thinking skills.

Based on the differences between the two classes, namely the experimental class and the control class, it proves that the PBL model with the STEM approach can be categorized as more effective and efficient to use in the learning process than learning in the experimental class. In PBL learning, problems are used to stimulate and focus student learning activities. The application of PBL with the STEM approach can give students the freedom to analyze, evaluate, create, and make the right decisions in solving predetermined problems. Problem solving with the STEM approach has the main principle of linking communication, material ability to solve technology integration problems and work. This approach focuses on the learning process of solving problems in real life. Furthermore, in the reserach of Miller & Krajcik (2019) that PBL learning through the STEM approach will help students develop their thinking skills and improve students' skills.

Conclusion

Based on the research and results of the analysis above, it can be concluded that there was an increase in HOTS and the learning activities of experimental class students using the PBL learning model with the STEM approach. This was proven based on the paired sample test of 0.001<0.05. It is proven that there is a significant influence on the implementation of PBL with the STEM approach in HOTS and the learning activities of junior high school students. The effectiveness of using the PBL model with the STEM approach received positive responses from students, where students were very enthusiastic in their learning activities. So that the use of PBL with the STEM approach can increase student learning activities in the learning process.

Acknowledgement

This research was research funded by the University of Jember's LP2M as part of a research collaboration with contract number 3554/UN25.3.1/LT/2023. In addition, the thanks also give to SMPN 2 Ajung Jember for providing the opportunity to collect data for this study.

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