UJME 12 (3) 2023: 270-279
UNNES JOURNAL OF MATHEMATICS EDUCATION
https://journal.unnes.ac.id/sju/index.php/ujme/
ISSN: 2252-6927 (print); 2460-5840 (online)

Effectiveness of Problem Based Learning Integrated STEAM on Students' Mathematical Problem Solving Ability

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ARTICLE INFO

Article history:
Received 5 May 2023
Received in revised form 2 November 2023
Accepted 30 November 2023

Keywords:
Effectiveness; Problem Based Learning; STEAM; Mathematical Problem Solving Ability.

Abstract

This study aims to determine the effectiveness of the Problem Based Learning (PBL) integrated STEAM on students' mathematical problem solving abilities. The population in this study were students of class VIII in Junior High School 1 Pringapus. The sample in this study were students of class VIII B as the experimental group and class VIII A as the control group. The sampling technique in the quantitative method in this study used a simple random sampling technique. The data collection technique used in this study was a test technique to obtain data on students' mathematical problem solving abilities. Based on the results of the study, it can be concluded that: (1) the average test results for students' mathematical problem solving abilities using the PBL integrated STEAM achieve individual completeness of 75; (2) the proportion of students' mathematical problem solving ability test results using the PBL integrated STEAM achieves 85% classical completeness; (3) the average test results for students' mathematical problem solving abilities with the PBL integrated STEAM are more than the average test results for students' mathematical problem solving abilities with the PBL; (4) the completeness proportion of students' mathematical problem solving ability test results using the PBL integrated STEAM is more than the completeness proportion of students' mathematical problem solving ability test results using the PBL. So, it can be concluded that the PBL integrated STEAM is more effective than the PBL.

1. Introduction

Education is an important milestone for a nation to achieve progress and prosperity for all its citizens. This is very common, because the progress of a nation can also be reflected based on the quality of the nation's education. Quoting from National Education Law Number 20 of 2003, education is a planned effort to create a learning atmosphere and learning process so that students are able to actively develop their inner potential so that they have the skills needed by them, religious spiritual strength, as well as self-control, personality, intelligence, noble character, which is useful for society, nation and state (UU No. 20 of 2003 National Education System, 2003). However, special education in the Indonesian nation must retain its character and reflect the wisdom embodied in the lives of the Indonesian people. This is in accordance with Suwartini (2017), where education in Indonesia aims to develop its potential as students in an effort to make them human beings who are pious and believe in God Almighty and have noble character and according to the wisdom of the Indonesian people.

Education consists of several elements, where one of the elements in education is mathematics as educational material/content (Sulindawati, 2018). The magnitude of the role of mathematics as the root of knowledge can be seen in the large demands on mathematical abilities that must be possessed (Anwar, 2018). As for its application, mathematics learning must meet standards as a benchmark for the quality of mathematics learning so that learning takes place as expected. NCTM (2000) suggests that one of the

To cite this article:
Rahmatjati A. M., Ardiansyah A. S., & Rochmad (2023). Effectiveness of Problem Based Learning Integrated STEAM on Students' Mathematical Problem Solving Ability. *Unnes Journal of Mathematics Education*, *12*(3), 270-279. doi: 10.15294/ujme.v12i3.78959

competency standards in learning mathematics that needs to be achieved is mathematical problem solving. This standard is reinforced by Depdikbud (2006), that one of the goals in learning mathematics is to make students have problem solving skills which include the ability to understand problems, design strategies and mathematical models, complete models and conclude solutions to problems obtained. This shows the importance of the ability to solve mathematical problems in education.

In the process, the ability to solve mathematical problems has not been made the main focus of learning activities, in which this application has become the core of mathematics learning activities in many developed countries such as Japan and America (Arifin, 2019). Of course, in supporting this effort, clear mapping is needed regarding the stages of problem solving in the application of learning. Polya (1973) states that the steps for solving mathematical problems include (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) look back at the completed solution. This view regarding the importance of mathematical problem solving skills is based on the fact that problem solving abilities are one of the objectives of learning mathematics that must be achieved by students (Agustami et al., 2021). Problem solving ability is a very important goal of learning mathematics both in the context of mathematics and outside the context of mathematics such as real life, science, and technology (Astutiani et al., 2019). According to Branca, that how important problem solving skills are for students to have is because, (1) the general goal of teaching mathematics is problem solving; (2) the main and core process in the mathematics curriculum is problem solving which includes methods, procedures and strategies; and (3) the basic ability to learn mathematics is problem solving (Purba, 2019).

When studied in more depth, the root of the problems in learning mathematics in Indonesia can be seen from the low achievement in various international surveys. According to PISA (2019), the results of the 2018 PISA survey placed Indonesia in 72nd place out of 78 countries in the area of mathematical ability. This bad fact is reinforced by the results of a survey (TIMSS, 2015), which Indonesia ranks 44th out of 49 participating countries in mathematics ability. The fact that Indonesia is ranked low in two international surveys by PISA and TIMSS in the field of mathematics ability shows how problematic the world of mathematics education is in Indonesia.

To find out the reality of educational problems in the field of mathematics, a preliminary study was conducted to find out the math problem solving skills of class VIII students of Junior High School 1 Pringapus by using one of the prerequisite materials for Flat Side Shapes, namely Quadrilaterals and Triangles. The preliminary study test questions consisted of 3 items that were tested on 98 students from 3 classes. The assessment results from the preliminary study show a very bitter reality that the students' mathematical problem solving ability is very low with an average score of 12,6 out of the minimum completeness criterion score of 75. This result seems to emphasize the problem of education in mathematics in Indonesia which has been raised in the survey PISA 2018 and TIMSS 2015 that have been proposed previously.

In this case, to overcome the low ability of students to solve mathematical problems in learning, an innovative learning is needed because of the importance of solving mathematical problems (Rofiqoh et al, 2016). In this case one of the learning innovations that is able to develop mathematical problem solving skills is the Problem Based Learning (Geni & Hidayah, 2017; Vendiagrys et al, 2015). Meanwhile, according to Arends (2012: 396) that the essence of Problem Based Learning consists of presenting students with authentic and meaningful problem situations as a springboard in investigations and solving problems. Problem Based Learning or in Indonesian means problem-based learning is a systematic form of learning activity that applies the concept of skills in the 21st century where the teacher acts as a learning facilitator for students to solve problems innovatively (Mayasari et al., 2016). Arends (2012: 399) reveals the advantages of Problem Based Learning namely: 1) Problem Based Learning encourages collaboration and completion of joint tasks: 2) Problem Based Learning encourages observation and dialogue with others so that students can gradually take on the role observed through problem; 3) Problem Based Learning makes students actively involved in their own investigations which allows them to interpret and explain real world phenomena and build their own understanding of these phenomena. This of course further strengthens the idea of the importance of applying the Problem Based Learning for the world of education, especially for students.

Also, it is important to add an educational breakthrough in Indonesia that seeks to develop humans who can create a science and technology-based economy, namely STEAM integration (Wijaya et al., 2015). According to Nurhikmayati (2019) STEAM is a meta-discipline that integrates science, technology,

engineering, art and mathematics into an integrated approach that can be implemented in learning. Integration of STEAM will be able to present new possibilities for implementing the learning process with good problem solving abilities to students (Katz-Buonincontro, 2018). Nurhikmayati (2019) added that the implementation of STEAM in learning is a process of applying ideas, ideas and concepts contained in meta-disciplines in a learning which is expected to improve abilities both in the cognitive, affective and psychomotor aspects of students in dealing with technological advances. In addition, with integration STEAM Learning can also be delivered in an interesting and fun way, so that it is more meaningful for students (Viona et al, 2023).

According to Fathurrahman et al. (2019) learning effectiveness is effective teaching behavior shown by educators who are able to provide new experiences through specific approaches and strategies to achieve learning objectives. In line with this, Rohmawati (2015) revealed that learning effectiveness is a measure of the success of the interaction process in educative situations to achieve learning goals. Achievement of the learning objectives in this case is complete learning as stipulated by the Depdikbud that students are said to have completed learning if they obtain a minimum score of 75 from the ideal score and complete classically if at least 85% of the total number of students complete learning (Munjiati, 2021). Considering this, the effectiveness referred to in this study is the mathematical problem solving ability of students in the Problem Based Learning integrated STEAM fulfilling the following criteria: (1) achieve individual completeness ; (2) achieve classical completeness ; (3) the average test results are more than the average test results in the Problem Based Learning; (4) the completeness proportion of test results is more than the completeness proportion of test results in the Problem Based Learning.

However, the progress and welfare of all citizens of a nation depend on education, where one of the important elements in this education is mathematics. Mathematics learning must, of course, meet quality standards which in fact have not been made the main focus. As a result, student achievement, especially in math problem solving skills, was very low, both in general and specifically at Junior High School 1 Pringapus. To overcome this problem, innovative learning and new educational breakthroughs are needed that are proven to be able to improve students' mathematical problem solving abilities. Based on this background, the authors intend to carry out research to overcome the problems described above with the title "Effectiveness of Problem Based Learning Integrated STEAM on Students' Mathematical Problem Solving Ability ".

2. Methods

This study used a quantitative experimental research method. The research design used in this study was a true experimental design with a posttest-only control design as presented in Table 1 below.

Table 1. Research Design

Class	Treatment	Posttest
Experiment	V	P_1
Control		P_2

This research was conducted at Junior High School 1 Pringapus, which has an address at Street Siswa, Wonoyoso Village, Pringapus District, Semarang Regency in February 2023. The population in this study were class VIII students at Junior High School 1 Pringapus. The sample in this study were students of class VIII B as the experimental group and class VIII A as the control group. The sampling technique in the quantitative method in this study used a simple random sampling technique where the sample was taken simply because the sampling of members of the population was done randomly without regard to other factors. Class VIII B as the experimental group was given treatment in the form of a Problem Based Learning integrated STEAM and class VIII A as the control group was given treatment in the form of a Problem Based Learning.

The data collection technique used in this study is the test technique. The test technique was used to obtain data on students' mathematical problem solving abilities in the experimental group and the control group. The tests used in this study were tested for validity, reliability, discriminating power, and difficulty index tests. The data analysis technique used in this study is the prerequisite test, namely the normality test

and homogeneity test as well as the hypothesis test which includes individual completeness tests, classical completeness tests, two average difference tests, and two proportion difference tests, to test the effectiveness of the Problem Based Learning integrated STEAM.

3. Results & Discussions

Problem Based Learning integrated STEAM process was carried out in the experimental group carried out in 3 meetings where learning was carried out according to the syntax of the Problem Based Learning integrated STEAM consisting of 5 phases. In the preliminary activity, one of the students led to pray first to start the learning activity, followed by the students paying attention to motivation, learning objectives, and what benefits would be obtained by studying the material. Students are also given an explanation regarding the prerequisite material which is related to the material Volume of Flat Side Spaces Building that will be studied.

In the core activities of phase 1, namely orient students to the problem, students examine and analyze STEAM nuanced problems given in the problem sheet. In phase 2, namely organize students for study, students are divided into 8 groups consisting of 4-5 students to discuss matters in the material to answer STEAM nuanced problems in the Problem Sheet and identify and analyze things that are not yet understood to be asked related to nuanced issues STEAM in the Problem Sheet. In phase 3, namely assist independent and group investigation, students discuss related steps for solving and strategies and solving STEAM-nuanced problems in problem sheets. Some students ask questions related to the steps and strategies for completion, the teacher invites other students to answer and give opinions. Furthermore, students in each group discussed to solve the problem. Students who have difficulty solving problems are guided individually or in groups. In phase 4, namely develop and present artifacts and exhibits, students collect the results of group discussions related to working on STEAM nuanced problems in problem sheets. Groups of students are welcome to present their work and the teacher invites other students to discuss and provide feedback. In phase 5, namely analyze and evaluate the problem solving process, students discuss to make conclusions about what has been learned and students are given the opportunity to ask questions again about things that have not been understood. In the closing activity, the teacher provides information related to material that must be studied at home for the next meeting.

As for the fourth meeting, a mathematical problem solving ability test was carried out to obtain data on the results of the mathematical problem solving ability test in the experimental group and the control group. Data acquisition from the experimental group was data on mathematical problem solving ability tests using the Problem Based Learning integrated STEAM, while data acquisition from the control group was data on mathematical problem solving ability tests using the Problem Based Learning. This data is then analyzed to test the effectiveness of the Problem Based Learning integrated STEAM compared to the Problem Based Learning.

Based on the data obtained in the study, a normality test was carried out to find out whether the research data came from a normally distributed population or not. The normality test used in this study is the Kolmogorov-Smirnov test with the help of SPSS 26. The calculation of the data normality test is presented in the following table.

Table 2. Calculation of Normality Test

	Control Group Data	**Experimental Group Data**
Sig.	0.175	0.095
Decision	H_0 accepted	H_0 accepted

Based on the calculation of the normality test, with a significant level $\alpha = 0{,}05$ and the test criteria H_0 accepted if the $sig > 0{,}05$. As for the data from the control group, a value was obtained $sig = 0{,}175 > 0{,}05$, means H_0 accepted, and from the experimental group data, it was obtained a value $sig = 0{,}095 > 0{,}05$, means H_0 accepted. So, the control group and experimental group data come from populations that are normally distributed, which also means that the statistics used in this study are parametric statistical tests.

The homogeneity test was carried out to find out whether the research data in the form of test data for students' mathematical problem solving abilities in the experimental group and the control group had a

homogeneous variance or not. The calculation of the data homogeneity test is presented in the following table.

Table 3. Calculation of Homogeneity Test

Sig.	**Testing**	**Decision**
0.873	$0.873 > 0.05$	H_0 accepted

Based on the calculation of the homogeneity test, with a significant level $\alpha = 0{,}05$ and the test criteria H_0 accepted if the *sig value* > $0{,}05$. Through the calculation of the homogeneity test obtained $sig = 0{,}873 > 0{,}05$, means H_0 accepted. So, the test data from the experimental group and the control group have a homogeneous variance, both groups have the same variance. With this the prerequisite tests, namely the normality test and homogeneity test in this study were fulfilled.

Individual completeness tests were carried out to determine aspects of the mathematical problem solving abilities of students who received learning with the Problem Based Learning integrated STEAM to achieve individual completeness of 75. Individual completeness tests used the t-test and the calculation is presented in the following table.

Table 4. Calculation of Individual Completeness Test

$\bar{x}$	μ_0	s	n	t_{count}	t_{table}	**Decision**
84.14	75	4.73	32	10.91	1.70	H_0 rejected

Through the calculation process, the value is obtained $t_{count} = 10{,}91$ and $t_{table} = 1{,}70$. The test criterion is if $t_{count} \geq t_{table}$, then reject H_0. These results indicate that $t_{count} \geq t_{table}$ means H_0 rejected and H_1 accepted. So, the average test results for students' mathematical problem solving abilities in the Problem Based Learning integrated STEAM achieve individual completeness.

The classical completeness test was carried out to determine aspects of the mathematical problem solving ability of students who received learning with the Problem Based Learning integrated STEAM to achieve a classical completeness proportion of 85%. The classical completeness test used the z proportion test. The calculation of the classical completeness test for the data is presented in the following table.

Table 5. Calculation of the Classical Completeness Test

x	n	π_0	**Completeness Proportions**	z_{count}	z_{table}	**Decision**
30	32	0.85	93.75%	1.080	0.1736	H_0 rejected

Through the calculation process, the value is obtained $z_{count} = 1.080$ and $z_{table} = 0.1736$. The test criterion is if $z_{count} \geq z_{table}$, then reject H_0. These results indicate that $z_{count} \geq z_{table}$ means H_0 rejected and H_1 accepted. So, the proportion of students' mathematical problem solving ability test results in the Problem Based Learning integrated STEAM achieves classical completeness.

The average result of the experimental group's mathematical problem solving ability test was 84,14 and that of the control group was 78,23, where these results indicated that the two classes had significantly different averages, where the average test result of the experimental group was more than the average test results of the control group. These results were strengthened by the two average difference t test which was conducted to test whether the average test results of students' mathematical problem solving abilities with the Problem Based Learning integrated STEAM were more than the average results of students' mathematical problem solving ability tests with the Problem Based Learning. The calculation of the difference t test for the two averages of the data is presented in the following table.

Table 6. Calculation of the Two Average Difference Test

$\bar{x_1}$	$\bar{x_2}$	s_1^2	s_2^2	n_1	n_2	t_{count}	t_{table}	**Decision**
84.14	78.23	22.373	21.809	32	31	28.64	1.67	H_0 rejected

Through the calculation results obtained $t_{count} = 28.64$ and $t_{table} = 1.67$. The test criterion is if $t_{count} \geq t_{table}$, then reject H_0. These results indicate that $t_{count} \geq t_{table}$ means H_0 rejected and H_1 accepted. So, the average test results for students' mathematical problem solving abilities in the Problem

Based Learning integrated STEAM are more than the average test results for students' mathematical problem solving abilities in the Problem Based Learning.

A two-proportion difference test was carried out to test whether the completeness proportion of students' mathematical problem solving ability test results with the Problem Based Learning integrated STEAM was more than the completeness proportion of students' mathematical problem solving ability test results with the Problem Based Learning. The difference test of these two proportions was carried out using the two proportion z test. The calculation of the difference test for the two proportions of the data is presented in the following table.

Table 7. Calculation of Two Proportion Difference Test

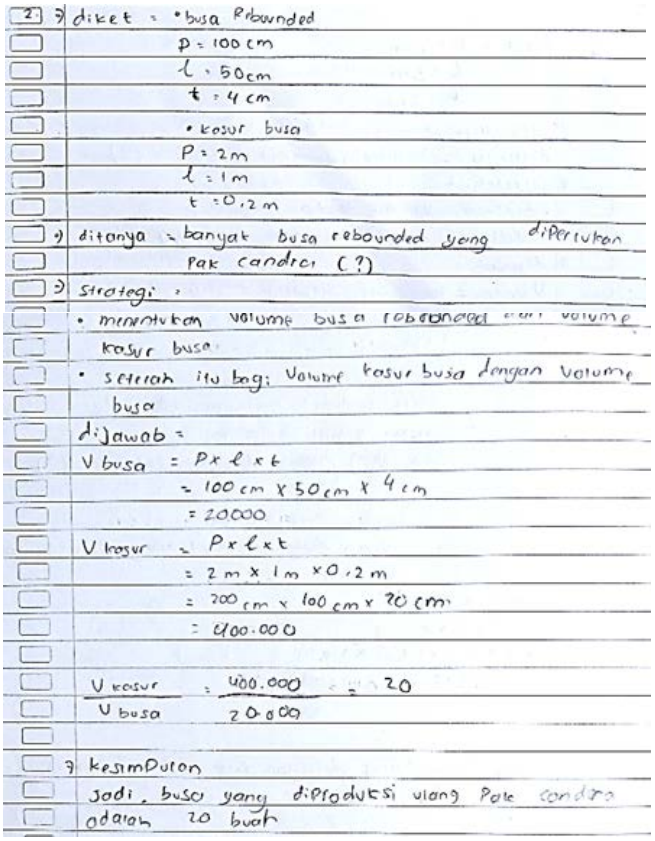
x_1	x_2	n_1	n_2	p	q	z_{count}	z_{table}	Decision
30	26	32	31	0.89	0.11	1.253	0.1736	H_0 rejected

Through the calculation process, obtained $z_{count} = 1{,}253$ and $z_{table} = 0{,}1736$. The test criterion is if $z_{count} \geq z_{table}$, then reject H_0. These results indicate that $z_{count} \geq z_{table}$ means H_0 rejected and H_1 accepted. So, the completeness proportion of students' mathematical problem solving ability test results in the Problem Based Learning integrated STEAM is more than the completeness proportion of students' mathematical problem solving ability test results in the Problem Based Learning.

Based on these results, it can be concluded that the Problem Based Learning integrated STEAM is more effective than the Problem Based Learning by fulfilling four criteria, namely individual completeness, classical completeness, the difference between two averages is more than than the class with Problem Based Learning, and the completeness proportion is more than the class with Problem Based Learning. These results prove the effectiveness of the Problem Based Learning integrated STEAM compared to the Problem Based Learning.

Moreover, these results are reinforced by samples of the work by students with high mathematical problem solving abilities from the experimental group and the control group as follows.

a.



b.

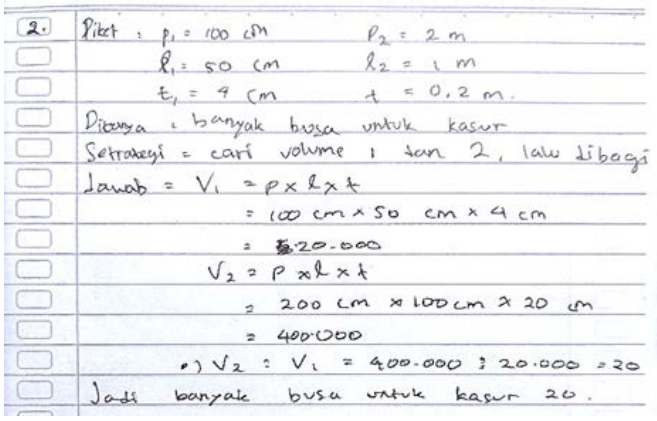


Figure 1. (a) work of students in experimental group; (b) work of students in control group

It appears that the results of the work of students from the experimental group who received Problem Based Learning integrated STEAM wrote down what was known and what was asked about the problem in more detailed and clear, which showed that the experimental group students were better at solving mathematical problems, namely understanding the problem compared to control group students. The students in the experimental group were also more detailed and clear in the steps of solving mathematical problems, namely devising a plan compared to students in the control group. Furthermore, students in the experimental group made more detailed and complete conclusions in the steps of solving mathematical problems, namely look back at the completed solution compared to students in the control group. Based on this example, the application of Problem Based Learning integrated STEAM makes students better at carrying out mathematical problem solving steps, namely understanding problems, devising a plan, and look back at the completed solution compared to students in the control group. This at the same time reinforces the findings in this study that Problem Based Learning integrated STEAM is more effective than Problem Based Learning alone.

At last, this result can occur because the learning model of Problem Based Learning and integration of STEAM in other research results is proven to have added value which makes it more effective than just Problem Based Learning. The results of research by Sumartini (2016) and Sariningsih et al. (2017), which proves that there is an increase in the mathematical problem solving ability of students who receive problem based learning is better than students who receive conventional learning model. Further on this, evidence was also obtained from Yanti (2017) which in addition to proving an increase in the problem solving abilities of students taught using the Problem Based Learning is better than conventional learning model. But not only that, the learning model tested in this study was also given STEAM integration which has more value in this study, namely the Problem Based Learning integrated STEAM to further improve students' mathematical problem solving abilities. The results of Ifyanti et al. (2022); Putri et al. (2021) and Ubaidah et al. (2020), proved that STEAM integration improves students' mathematical problem solving abilities. The integration of STEAM will be able to present new possibilities for implementing the learning process with good problem solving abilities to students (Katz-Buonincontro, 2018). In addition, according to Nurhikmayati (2019) STEAM learning which integrates several disciplines is very interesting to do, where students will be more motivated in learning mathematics because the variety of learning includes elements of science, technology, engineering and art. The combination of the Problem Based Learning which is proven to improve mathematical problem solving abilities with STEAM integration which is also proven to increase mathematical problem solving abilities synergized and become one, that makes students' mathematical problem solving abilities more improved compared to students' mathematical problem solving abilities in the Problem Based Learning alone. So, it proved the effectiveness of the Problem Based Learning integrated STEAM on students' mathematical problem solving abilities compared to the Problem Based Learning in this study.

4. Conclusion

Based on the results of the study, it can be concluded that: (1) the average test results for students' mathematical problem solving abilities using the Problem Based Learning integrated STEAM achieve individual completeness of 75; (2) the proportion of students' mathematical problem solving ability test results using the Problem Based Learning integrated STEAM achieves 85% classical completeness; (3) the average test results for students' mathematical problem solving abilities with the Problem Based Learning integrated STEAM are more than the average test results for students' mathematical problem solving abilities with the Problem Based Learning; (4) the completeness proportion of students' mathematical problem solving ability test results using the Problem Based Learning integrated STEAM is more than the completeness proportion of students' mathematical problem solving ability test results using the Problem Based Learning. So it can be concluded that the Problem Based Learning integrated STEAM is more effective than the PBL.

Through the results of this study, the researcher provides the following suggestions: (1) teachers can consider using the Problem Based Learning integrated STEAM as an alternative learning model in order to obtain better mathematical problem solving skills; and (2) teachers can consider the use of mathematical problem solving ability steps in learning mathematics so that students are trained in every process of solving problems and are able to improve mathematics learning outcomes optimally.

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