24 (1), 2023, 349-358

Jurnal Pendidikan MIPA

e-ISSN: 2685-5488 | p-ISSN: 1411-2531

http://jurnal.fkip.unila.ac.id/index.php/jpmipa/

Implementation of STEM-Integrated Problem Based Learning to Improve Students' Problem Solving Skills in Liquid Pressure

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Abstract: This research aims to describe the skills of students through the application of STEM-integrated Problem Based Learning on liquid pressure. The subjects of this study were 30 public junior high school students in Surabaya. The type of research was quantitative research. The research design is a quasi-experimental. The research instrument used was a problem-solving skills sheet with indicators: making plans, implementing plans and reviewing results. The data analysis technique used consists of: 1) prerequisite test; 2) Independent t test; and 3) n-gain. The results of the recapitulation of the n-gain category can be seen that 28 students got high selection and 2 students got medium selection. Based on the results obtained, it shows that the STEM-integrated Problem Based Learning has an effect on students' problem-solving skills.

Keywords: problem solving skills, problem based learning, STEM.

Abstrak: *Penelitian ini bertujuan untuk mendeskripsikan keterampilan pemecahan masalah peserta didik melalui penerapan Problem Based Learning berbasis STEM pada materi Tekanan zat cair. Subjek penelitian ini berjumlah 30 peserta didik SMP Negeri di Surabaya. Jenis penelitian yang digunakan adalah penelitian kuantitatif dan diolah menggunakan metode statistik. Desain penelitian ini adalah quasi eksperiment. Instrumen penelitian yang digunakan berupa lembar tes keterampilan pemecahan masalah dengan indikator: menyusun rencana, melaksanakan rencana dan melihat kembali hasil. Teknik analisis data yang digunakan terdiri dari: 1) Uji prasyarat; 2) Uji t saling bebas; dan 3) N-gain. Hasil rekapitulasi kategori N-Gain dapat dilihat bahwa 28 peserta didik mendapat kriteria tinggi dan 2 peserta didik mendapat kriteria sedang. Berdasarkan hasil yang diperoleh tersebut menunjukkan bahwa model pembelajaran Problem Based Learning terintegrasi STEM berpengaruh dalam keterampilan pemecahan masalah peserta didik.*

Kata kunci: *keterampilan pemecahan masalah, problem based learning, STEM.*

▪ INTRODUCTION

Education in the 21st century includes education that creates an active teaching and learning atmosphere in developing technology-based potential, intelligence, skills, and personality of a person (Peters-burton & Stehle, 2019). Education in the era of globalization encourages giving challenges to aspects of life, one of which is quality human resources. Qualified human resources must have expertise or skills that are reflected in the competency framework 21st Century Skills (Garner et al., 2018). Natural Sciences includes science that plans the long term to create knowledgeable, talented, highly skilled, and productive human resources (Betti, 2021). Science and technology are used to meet needs in the era of globalization (Alcácer & Cruz-Machado, 2019). Natural Science is included in the procedure for solving problems. These problem solving skills are included in the important skills in learning science.

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DOI: http://dx.doi.org/10.23960/jpmipa/v24i1.pp349-358
Received: 30 May 2023
Accepted: 13 July 2023
Published: 22 July 2023

This science learning provides understanding to students to solve problems that exist in everyday life (Vennix et al., 2018).

Problem solving skills are an important component in solving problems because they can develop a logical, systematic and creative mindset in students (Polya, 1978). Problem solving skills include abilities that connect the processes of analysis, reasoning, prediction, reflection about what happens in daily activities (Anderson, 2019). This problem solving skill is used in learning as a scientific method with a critical, logical and systematic mindset so that it can solve problems thoroughly with rational thinking (Frey, 2022). Students who are successful in learning new concepts and develop problem-solving abilities if the students themselves are able to solve the problems they face (Saidah & Nurita 2017). Problem-based learning is learning that demands students' thinking abilities optimally through a systematic process of group or team work, so that students themselves can empower, hone, test, and develop their skills (Ghattas & Willcox, 2021).

Learning innovations that can be applied to improve problem solving skills using the STEM (Science, Technology, Engineering, Mathematics) based Problem Based Learning (PBL) model. Mastery of science and technology is one of the keys to success in the 21st century, one of which is the STEM learning model (Anggraini & Nurita, 2021). This learning model raises existing and meaningful problems, so that these problems serve as a springboard for students to conduct investigations (Arends, 2017). In STEM learning, it can train students to apply their knowledge by making designs as a medium for solving problems related to problems that exist in the environment by utilizing technology (Peters-burton & Stehle, 2019). STEM-based learning expects students to be able to think critically, creatively and innovatively which can later solve real problems through group activities (Craggs, 2021).

STEM-based PBL learning can be applied to Liquid Pressure material and its Application in Everyday Life. In this PBL learning students can connect real-life concepts which will later be useful for understanding learning easily and can find their own solutions to problem solving. Indicators of problem solving skills or what is called problem solving characterizes a person to complete his problem solving skills. Problem solving indicators according to Polya (1978) include: understanding the problem, planning a settlement (developing a settlement plan), solving the problem according to plan (implementing the plan), and re-examining the results. Based on the results of observations using problem-solving skills instruments that have been validated in February 2023 at one of the Surabaya State Middle Schools, the results include: on the indicator of understanding problems, results are obtained with a percentage of 60%; indicators of compiling a settlement plan get a yield of 32.56%; indicators of carrying out the plan to get results of 21.61%; and the indicator sees a yield return of 32.93%.

Science learning is related to technology where the development of globalization civilization can be supported by the use of technology (Rai, 2020). This can be integrated into STEM-integrated Problem Based Learning which is oriented towards science, technology, engineering, and mathematics. In STEM-based learning, students can improve their higher-order thinking skills, problem-solving skills, and collaboration skills. This is in line with research conducted by Betti (2021), Craggs (2021), Nailul (2020), and Lynch et al (2018) which say that STEM-based learning can improve

problem solving skills. This shows that STEM-based PBL learning can have a positive impact on learning.

▪ METHOD

Participants

The research subjects were 30 class VIII students of one of the Public Middle Schools in Surabaya. The sampling technique used was not chosen randomly (non-randomly sampling), but was determined beforehand (Isnawan, 2020). The sampling technique uses a selected sample based on the subjectivity of the researcher and is not carried out randomly.

Research Design and Procedures

The research design used is quasi-experimental. The type of research used is quantitative research using numerical data and processed by statistical methods. Quantitative research is useful in certain sample studies, collecting and using instruments in research, analyzing quantitative or statistical data (Sugiyono, 2016). The time of the research was conducted from February to May 2023.

Instruments

The instrument used is an instrument that has been validated by experts according to problem solving indicators. This instrument was adopted from Wirdatul Almira's research (2020), which consisted of6 essays and adapted to indicators of problem solving skills which consist of: making plans, carrying out plans and reviewing results. Then, an analysis is carried out based on the achievement indicators of problem solving skills.

Data Analysis Technique

The data analysis technique used consists of: 1) prerequisite test; 2) Independent t test; and 3) N-gains. The prerequisite test consists of a homogeneity test and a normality test. The homogeneity test aims to determine whether the data is homogeneous or not. If homogeneity is met, then the data analysis phase can be carried out, and if the results are not shown, there must be improvement in the methodology. Normality test aims to assess the results of group data distributed normal or not. Kolmogorov-Smirnov are used to assess the normality data. The t-test is used if the data that has been tested has a normal distribution (close to normal) and has the same variance. N-gain is carried out to test the hypothesis by comparing the average gain and the average maximum gain.

Table 1. N-gain category

No	N-gain	Category
1.	$\langle g \rangle \geq 0.7$	High
2.	$0.7 > (\langle g \rangle) > 0.3$	Middle
3.	$(\langle g \rangle) \leq 0.3$	Low

▪ RESULT AND DISSCUSSION

The quasi-experimental method provides a change from the treatment that has been given using the STEM-integrated Problem Based Learning. In this study using the independent variable STEM-integrated Problem Based Learning. STEM-integrated

Problem Based Learning is learning that combines four STEM subjects in one particular lesson on the basis of subject relationships and problems in everyday life (Moore, 2014). While the dependent variable in this research is problem solving skills. Problem solving skills are a thinking process in solving a problem by gathering facts, information, preparing solutions to selecting solutions to problems (Bancong, 2021). Based on the analysis, the following results were obtained:

Homogeneity Test

The homogeneity test aims to determine whether the data is homogeneous or not. Following are the results of the homogeneity test:

Table 2. Homogeneity test results

		Levene Statistic	df1	df2	Sig.
Hasil	Based on Mean	3.928	1	58	.052
	Based on Median	4.035	1	58	.049
	Based on Median and with adjusted df	4.035	1	47.847	.050
	Based on trimmed mean	3.818	1	58	.056

Based on the results of homogeneity test with significance level used is α= 0.05 using SPSS with the criteria for drawing conclusions. If F_{count} is greater than F_{table} then it has variant which is homogeneous (Sugiyono, 2016). From the results of the homogeneity test that has been carried out, it is known that the significance value based on mean of 0.52 > 0.05, significance based on median of 0.49>0.05, so the variance of the data is homogeneous.

Normality test

Normality test aims to and assess the results of group data distributed normally or not. This study use Normality test of Kolmogorov-Smirnov. The results is presented in the following table:

Table 3. Normality test result

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Hasil Keterampilan Pemecahan Masalah	.160	30	.047	.940	30	.089

a. Lilliefors Significance Correction

This 'normality' test uses the Kolmogorov-Smirnov SPSS. 'The significance level used is α = 0.05. Based on the results of the normality test using Kolmogorov Smirnov, it can be known that it has a significance of >0.05, so the residual values of the data are normally distributed. Next, a one sample t-test can be carried out.

One sample t-test

One sample t-test is used to compare the average sample under study with the existing population average. This one sample t-test is used to test hypotheses in statistics and is part of parametric statistics, where the basic assumption that must be met is that the research data is normally distributed.

Table 4. The result of one sample t-test

	Test Value = 75					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Hasil Keterampilan Pemecahan Masalah	11.943	29	.000	15.733	13.04	18.43

Based on the test using the one sample t-test, it can be seen that the sig. (2-tailed) of 0.000 <0.05, so it can be concluded that the "Hypothesis is accepted". The results of the study show that applying STEM-integrated Problem Based Learning can improve problem solving skills. Students are active in activities that are appropriate to the learning steps. The application of STEM-integrated Problem Based Learning students can be more active in solving problems that are relevant to learning objectives, gain new knowledge and be able to develop the skills they have (Andarini, 2020).

N-Gain analysis

This analysis was carried out to test the hypothesis using the N-gain formula in the form of a comparison between the average gain obtained. The following is the N-Gain category recapitulation data:

Table 5. N-gain category for each indicator

No	Indicators	N-gain	Category
1.	Create completion plan	0.8	High
2.	Doing the plan	0.95	High
3.	Review the results	0.96	High

In the recapitulation of the N-Gain category, it can be seen that the indicators for compiling a settlement plan get an n-gain of 0.8 in the high category; on the indicator of carrying out the plan to get n-gain of 0.95 in the high category; and the indicator looks back at the results of getting an n-gain of 0.96 in the high category. Based on the results of the n-gain test on each indicator of the liquid pressure material sequentially from high to low, there is the first indicator, looking back at the results, the second is carrying out plans and the third is to draw up a settlement plan. Details of problem solving skills for each indicator can be seen based on the details and presentation as follows:

Create completion plan

On the indicator of compiling a settlement plan, results are obtained in the high category. That is, students are able to devise a settlement plan. Students can think of

steps to solve the problems they face. This thinking ability can be exercised if students acquire sufficient knowledge or the problems encountered are not new but similar (Betti, 2021). The following are the results of student documentation:

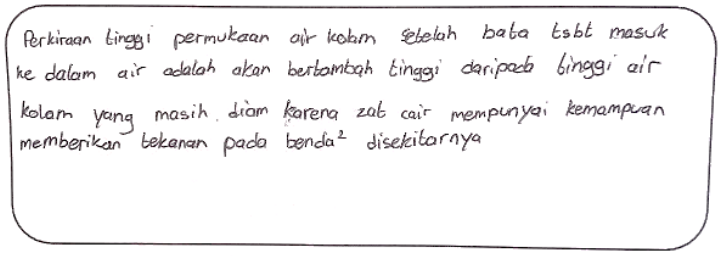
Perkiraan tinggi permukaan air kolam setelah bata tsbt masuk ke dalam air adalah akan bertambah tinggi daripada tinggi air kolam yang masih diam karena zat cair mempunyai kemampuan memberikan tekanan pada benda² disekitarnya

Figure 1. Documentation of the results of students' problem solving skills on preparing a completion plan

Based on the documentation, it appears that students on this indicator have been able to prepare a settlement plan. Students must be able to find supporting concepts or theories. In addition, students also have to look for formulas if needed. This is based on the development of students who are required to think about what steps to take (Ramadhani & Nurita, 2022). Develop a settlement plan including the first steps in solving the problem to be resolved (Kim et al., 2018).

However, there are some students who have moderate or low scores. Students who get this value are because they cannot develop a settlement plan because students do not pay attention when the teacher explains, students are engrossed in playing alone, do not focus on learning so students cannot develop a settlement plan (Bartholomew, 2017). If students cannot develop this settlement plan, then students cannot solve existing problems. Students must be able to find supporting concepts or theories. This problem-solving skill is marked by the work of students to solve problems that begin with planning through their own approach. This shows that students' problem-solving skills in implementing the STEM-based PBL learning model are going well by providing encouragement and experiences that help students to acquire problem solving and skills (Lou et al., 2019). STEM-based PBL learning is included in learning that focuses on students' experiences to learn responsibility for solving problems independently or with their groups (Lynch et al., 2018).

Doing the plan

In the indicator of carrying out the plan, results are obtained in the high n-gain category. The following are the results of the documentation of students' work on the indicators of carrying out the plan:

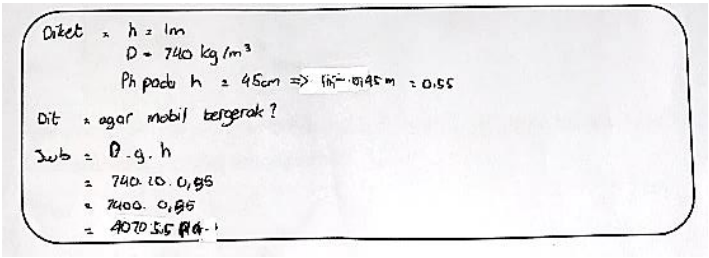

Figure 2. Documentation of students' problem-solving skills test results on the indicators of doing the plan

Based on the results of the documentation it appears that students are capable of carrying out the plan. Students are able to understand what problems they are facing, carry out what plans have been prepared, what must be done or completed first. Then enter the numbers into the formula that has been determined. The development of understanding and the ability to utilize facts is very important in science learning because it is very useful in everyday life (Trna et al., 2012). When students are able to apply their knowledge to a condition, they can be declared capable of carrying out and solving problems according to plan (Ssemugenyi, 2023). Students who carry out plans accompanied by technology to observe, analyze and implement plans related to STEM science can facilitate solving the problems they face (Robinson et al., 2014)

The process of integrating STEM in learning can encourage students to construct knowledge through a process of observation based on real experience (Betti, 2021). One of the characteristics of STEM-based PBL learning is that students solve problems found in everyday life by applying science and technology to facilitate problem solving (Gonzalez & Kuenzi, 2014).

Review the results

On the indicator, look back at the results of getting the high category n-gain. The following are the results of documenting the results of students' work on indicators looking back at the results:

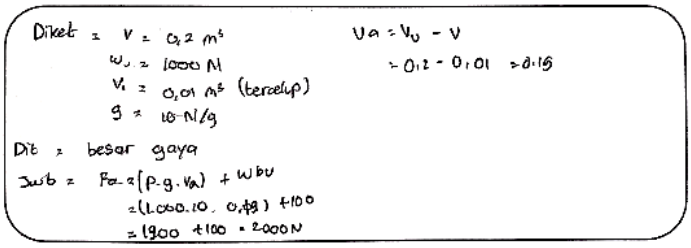

Figure 3. Documentation of students' problem-solving skills test results on indicator review the results

Students at this level are able to work on and get high categories. At this stage students try to check and review properly and thoroughly on every problem solving that is done (Robinson et al., 2014). In addition, a check was also carried out regarding the systematics and stages of completion. Students need to have cognitive abilities to see

the changes that occur (Quitadamo, 2018). But in reality there are still some students who are less thorough in reviewing the results obtained.

The acquisition of these students' problem-solving skills is essential to the knowledge they receive on the application of STEM-based Problem-Based Learning (Laforce et al., 2017). The learning time given to students can influence the level of mastery and understanding of STEM-integrated problem-solving skills (Garner et al., 2018). The results of the knowledge received by students consist of input processes, output processes and activation processes which can be seen based on the results of tests given to students on the level of difficulty in influencing their knowledge processes. (Ssemugenyi, 2023).

Problem Solving in this lesson trains students to develop and explore problems in everyday life so that later they can find answers to the problems they face on their own. STEM in this study is used as a learning model approach that combines the four subjects (Craggs, 2021). This learning uses STEM worksheets-based Problem Based Learning. Where aspects of science and technology are applied when students access barcodes that contain problem orientation and phet simulations to support students' initial understanding. The following is the documentation during the lesson:

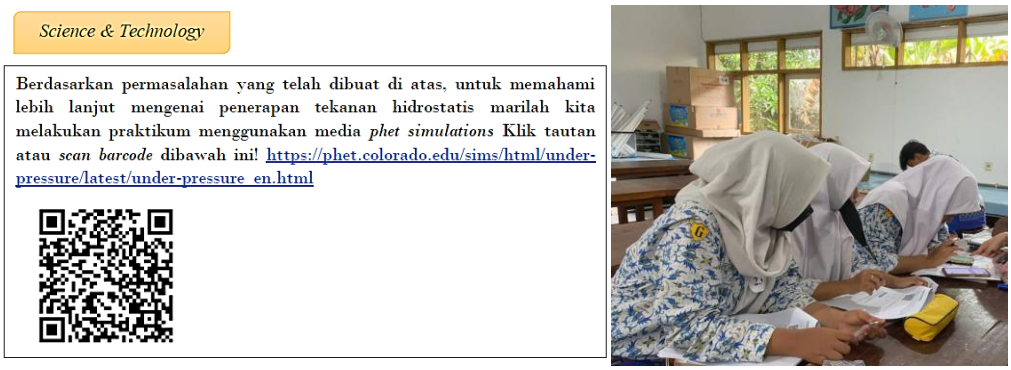

Figure 4. Learning documentation

Students are very enthusiastic because they feel something new in learning. The tools used when scanning barcodes use each handpone. This tool is used as well as possible when learning takes place. In the engineering aspect students describe the design regarding the solution to the problem to be solved. Whereas in the mathematics aspect students evaluate the problems that have been solved by recalculating when using the formula when calculating. During the learning process students feel very happy and enthusiastic in solving the problems being faced with their groups. STEM-based learning integrates scientific disciplines where the learning material obtained is the result of knowledge and technology that has been integrated with components of mathematics and engineering (Bybee, 2013). This shows that the application of the STEM-integrated Problem Based Learning has an effect on students' problem solving skills.

The results of this study are in line with previous research conducted by Betti (2021) with the results of his research that STEM-based learning can improve problem-solving skills. In addition, in line with research conducted by Nailul (2020), the results

of his research stated that STEM-based learning affects students' problem-solving skills. The learning process of STEM-integrated Problem Based Learning can improve students' problem-solving skills, learning outcomes, critical and creative thinking and increase students' motivation in participating in learning (Laforce et al., 2017). This learning can help students master science and technology learning and provide solutions to problems that exist in the real world.

▪ CONCLUSION

Problem solving skills are an attempt to find a way out of the difficulties of problems received to achieve goals. Problem solving can be seen as a process of looking at several steps in solving a problem. Based on the results of research conducted at one of the Public Middle Schools in Surabaya, it was stated that students' problem solving skills on liquid pressure material showed high results. The results obtained indicate that the STEM-integrated Problem Based Learning has an effect on problem solving skills. Suggestions that can be given are that STEM-based PBL learning is expected to be applied by educators in the learning process and can improve students' problem solving skills in science learning, the division of learning activity time must be carried out optimally because the learning process requires quite a lot of time, and conduct ongoing research for improvements in the implementation of STEM-based PBL learning on liquid pressure material that has an effect on increasing problem-solving skills.

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