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The Effect of the STEM-PBL Learning on Students' Learning Outcomes on Optical Concepts

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Abstract

This study aimed to determine the effect of STEM learning on Optical material on student learning outcomes at junior high schools. This study used a quantitative approach using a one-group pretest-posttest design. The population is the entire class of one of the junior high schools in Samarinda, Indonesia, with the sampling technique using random cluster sampling, which is only one class with a total of 31 students from class VIII. Data collection in this study uses test techniques to determine student learning outcomes. Data were analyzed using Paired Samples t-Test. The study showed a significant effect of STEM learning on learning outcomes. It was demonstrated based on the average value of learning outcomes which increased from 11.70 to 53.87, and the significance value of the paired sample t-test, which was smaller than 0.05, which was equal to 0.000 with an N-Gain test of 0.47, including the moderate category.

Keywords: STEM learning, Problem based learning, Learning outcomes

INTRODUCTION

Physics is one of the interesting subjects because it is directly related to real events and can be applied in everyday life. In addition, physics requires more understanding than memorization (Ibnah & Rosidin, 2018). Many students have difficulty learning physics, especially applying physics concepts in everyday life (Azizah & Yuliati, 2015). This situation stems from teachers' tendency during the classroom learning process not to provide examples of application in everyday life, even though by relating physics lessons to daily life, of course, learning will become more meaningful (Ibnah & Rosidin, 2018).

A common problem today is that teachers need innovative learning models to motivate students to learn (Luh et al., 2019). Using traditional learning models, teachers tend to make students feel bored during class (Darsani, 2019). Improper learning design impacts student learning outcomes, and designing innovative learning is undoubtedly a difficult task realized by teachers (Darsani, 2019). What is meant by learning outcomes is the ability that a student has after going through a learning experience (Herak, 2021). Learning outcomes arise from the teacher's assessments and the interaction of various sources of information provided to students and processed according to the student's previous understanding (Putri et al., 2020).

The teacher acts as a facilitator, motivator, and one of the alternative learning resources. One of the current learning approaches that strongly supports the creation of 21st-century skills is STEM-based learning (Izzah & Mulyana, 2021).

STEM is an interdisciplinary approach to learning in which students use science, technology, engineering, and mathematics in a real-world context to connect schools and the global world, building students' ability to compete in the new world (Rihhadatul'aysi et al., 2020). STEM-based learning can train students to apply their knowledge to design created to solve environmentally related problems by utilizing technology. STEM is a learning approach that is integrated into a variety of sciences. STEM allows students to learn academic concepts correctly by applying four disciplines. STEM-based learning also requires students to become innovators, problem solvers, and inventors who can think with confidence, technical and logical (Susanti, 2018). Learning through a STEM approach aims to equip students with a balance of soft and hard skills because the learning process takes place in active learning, which includes communication, collaboration, problem-solving, and creativity. The STEM approach to education aims to prepare students to be able to compete and be ready to work in their fields (Jayani & Ruffaida, 2020). From this perspective, STEM includes each discipline's content, skills, and mindset. Still, it also requires understanding how disciplines interact and how they support and complement each other (El Nagdi et al., 2018).

STEM applies to different fields of study or majors with varying levels of education. In STEM-based learning, students become (1) problem solvers, (2) innovators, (3) inventors, (4) reasoning, strengthening and developing newly given skills, and (5) developing themselves, (6) technological literacy (Nuraziza & Suwarma, 2018).

STEM can be integrated into a variety of learning models. A model is a plan or pattern used to compile a curriculum, design learning materials, and guide learning in the classroom. STEM learning can be associated with different learning models. One is the Problem Based Learning (Izzah & Mulyana, 2021).

Problem-based learning is learning that presents real life that requires real solutions (Aini et al., 2021). Teachers can guide, explore, and challenge students' thinking by incorporating real-world problems into science learning. The student becomes an independent owner of the problem as a subject of investigation (Abbott, 2016). PBL encourages the development of lifelong learning skills with open, reflective, critical, and positive learning attitudes (Adiwiguna et al., 2019). Indirectly, using PBL also helps students acquire the knowledge they need to solve environmental problems in the form of information or data, and are taken into account when choosing the right solution (Farwati et al., 2017). Students are expected to be taught the basics of scientific thinking and be able to develop thinking skills (Nurazmi & Bancong, 2021).

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Based on the research gap, the research on implementing the STEM-PBL model is small. So, according to Cahyaningsih's study, STEM-PBL significantly affects critical thinking skills and learning outcomes that are categorized as moderate. In addition, Laforce's research shows that problem-based learning can be a strategy to increase students' interest in STEM (Melati, 2019). STEM allows students to think at a higher level, with proven skills from observing, analyzing, and doing science as a way to solve problems with STEM (Nurazmi & Bancong, 2021).

METHOD

This research was carried out in class VIII of one of the junior high schools in Samarinda, Indonesia, with the sample of this study being class VIII-10 totaling 31 students. Sampling is carried out using the cluster random sampling technique, which takes data sources randomly (Sugiono, 2012). This study uses descriptive research to determine learning outcomes after applying STEM learning. This study also used the One Group pretest-posttest design. Table 1 shows one experimental class was given pretest and post-test questions. With this design, researchers can compare the state before with the state after the treatment.

Table 1. *One Group Pretest-Posttest* Research Design

0_1	X	0_2

Information,

0_1 = Pretest score (before being given STEM learning treatment)

0_2 = Posttest score (after being given STEM learning treatment)

X = treatment given by STEM learning

The data collection technique used in the research was a written test of 10 essay questions as an assessment instrument to measure student learning outcomes. The criteria for learning outcomes are presented in Table 2.

Tabel 2. Learning Outcomes Criteria

Score	Criteria
$80 \leq x \leq 100$	Excellent
$70 \leq x < 80$	Good
$60 \leq x < 70$	Enough
$50 \leq x < 60$	Less
$0 \leq x < 50$	Very Lacking

The data analysis technique used in this study used paired t-test. However, before conducting a hypothesis test, you must do a Normality test. The normality test is used to determine whether the sample is from a normally distributed population. The data normality test was carried out with the Kolmogorov-Smirnov One Sample test with a set significance level of 5%, where if the significance value > 0.05, then the sample came from a normally distributed population. At the same time, if the significance value < 0.05, the sample did not come from a normally distributed population.

If the data is normally distributed, the next test carried out is the homogeneity test. The homogeneity test is used to determine whether the sample is from the same population. The level of significance set in this test is 5%, where if the significance value > 0.05, then the population is homogeneous, while if the significance value < 0.05, then the population is not homogeneous.

We are determining hypotheses in this study using the Paired Sample T-test. This test is used to prove the presence or absence of a significant difference between the pretest and posttest results. The degree of significance used is 5%.

Where,

H_0: There was no significant difference between student learning outcomes before STEM learning was applied (pretest) and after applying STEM learning (posttest)

H_1: there are significant differences between student learning outcomes before STEM learning is applied (pretest) and after applying STEM learning (posttest)

Hypothesis H0 is rejected, and H1 is accepted if the value of the sig. (2-tailed) and the hypothesis H0 is accepted, and H1 is rejected if the sig value (2-tailed).

The n-Gain test could be a test that can give a diagram of the increment in learning result scores sometime recently and after the application of a strategy. The normal capacity of understudy learning results will be seen to be made strides utilizing equations concurring to Meltzer (2012).

$$\mathrm{N-Gain} = \frac{\mathrm{posttest} - \mathrm{pretest}}{\mathrm{max\,score} - \mathrm{pretest}}$$

To find out the provisions for improvement on the N-Gain test, please refer to Table 3.

Table 3. N-Gain Criteria

N-Gain Value	Criteria
$\mathrm{N-Gain} > 0,7$	High
$0,3 \leq \mathrm{N-Gain} \leq 0,7$	Moderate
$\mathrm{N-Gain} < 0,3$	Low

RESULTS AND DISCUSSION

We gave a pretest of students' initial abilities before STEM learning treatment. Several pretest data were obtained based on student scores on pretest questions totaling ten items of essays. Pretest questions are given to students prior to the STEM learning treatment presented in Table 4.

Table 4. Percentage of Student Pretest Results

Score	Classification	Number of Students	Percentage
$80 \leq x \leq 100$	Excellent	0	0%
$70 \leq x < 80$	Good	0	0%
$60 \leq x < 70$	Enough	0	0%
$50 \leq x < 60$	Less	0	0%
$0 \leq x < 50$	Very Less	31	100%

Based on the analysis in Table 3, 31 students out of 31 students are in the category of very lacking. Table 5 shows the student's posttest results after being given STEM learning treatment.

Table 5. Percentage of Student Posttest Results

Score	Classification	Number of Students	Percentage
$80 \leq x \leq 100$	Excellent	0	0%
$70 \leq x < 80$	Good	3	9.67%
$60 \leq x < 70$	Enough	1	3.22%
$50 \leq x < 60$	Less	22	70.96%
$0 \leq x < 50$	Very Less	5	16.12%

Based on the analysis in Table 5, there are five students in the less category, 22 students in the less category, one in the sufficient category, 3 in the good category, and no one in the excellent category.

After the data on student learning outcomes are known, a prerequisite test is carried out, namely the Normality Test. The Normality test used is the Kolmogorov-Smirnov One Sample test to determine whether the data is normally distributed or abnormally. The test results are seen in the learning outcomes before and after the provision of STEM learning presented in Table 6.

Table 6. Normality Test Results

		Unstandardized Residual
N		31
Normal Parameters^{a,b}	Mean	.0000000
	Std. Deviation	7.44127770
	Absolute	.210
Most Extreme Differences	Positive	.210
	Negative	-.115
Kolmogorov-Smirnov Z		1.167
Asymp. Sig. (2-tailed)		.131

Furhtermore, a homogeneity test was carried out to find out whether the sample came from a homogeneous or inhomogeneous population presented in Table 7.

Table 7. Homogeneity Test Results

Learning Outcomes			
Levene Statistic	df1	df2	Sig.
.172	1	60	.680

Based on Table 8, we can see the significant value of < 0.05, then H0 is rejected, and H1 is accepted. It means that STEM learning influences student learning outcomes.

Table 8. Paired Sample T-Test Results

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pretest Posttest	-42.161	8.521	1.530	-45.287	-39.036	-27.549	30	0.000

The N-Gain test provides an improved overview in the form of an increase in student learning outcome scores after the implementation of STEM learning. The results of the N-Gain test are presented in Table 9.

Tabel 9. N-Gain Test Results

	N	Minimum	Maximum	Mean	Std. Deviation
NGain_Skor	31	.38	.73	.4769	.08618
Valid N (listwise)	31				

The instruments used before and after treatment are ten essays for pretest and posttest questions. The questions made are adjusted to the STEM learning projects carried out by the student. The questions on questions are used to determine whether or not there is an influence of STEM learning on student learning outcomes.

The research data obtained on the pretest results showed as many as 31 students fall into the category of very lacking with a range of values below 50 and a percentage of 100%, which is still far from below the KKM (Minimum Completeness Criteria) that the school has applied. With an average score obtained on the pretest 11.70. Based on this, almost all students have a very low initial understanding of optical material.

The percentage of learning outcomes obtained by students in the posttest was 0% in the excellent category, 9,67% in the good category, 70,96% in the less category, and 16,12% in the very lack category. The average student learning outcomes only reached 53.87 because there were still students who obtained low or below KKM scores, and only a few achieved KKM scores.

Statistical analysis found that applied STEM learning significantly influences student outcomes. For the analysis of N-Gain test data, the resulting N-Gain score was 0.4, which means that greater than 0.3 and less than 0.7 means that the score falls into the moderate category (Hake, 1999).

The description above shows that STEM learning affects students' learning outcomes in junior high schools. The paired sample t-test proves it with a significance of 0.000, and the N-Gain test with a value of 0.47 in the moderate category. The success of STEM learning is in line with research by Melati (2019). STEM-PBL learning significantly influences critical thinking skills and cognitive learning outcomes with a moderate category. According to research by Gale et al. (2020), an analysis of the evidence of the Effectiveness of STEM Enforcement in Asian Student Learning outcomes shows that the application of STEM at the intermediate level in Asia helps improve student learning outcomes.

According to Wisnu Wibowo (2018), STEM learning equips students with basic science and technology skills that are seen through reading, writing, observation, and scientific work to live in society and solve problems related to daily life related to the sciences. Learning activities that use STEM learning require students to engage directly with STEM learning and seek information relevant to their own experiences. This follows the view of Stohlmann et al. (2012) that the effectiveness of STEM includes involving students in discussions, experiences, and discoveries to increase knowledge. According to Almuharomah et al. (2019), the teacher can integrate several basic skills into the STEM approach through habituation activities and project assignments for students who produce work. The STEM-PBL learning process requires students to create a work or design in each learning cycle. Implementation of the engineering aspect, where students are asked to apply the knowledge that has been learned to their work and design. In addition, there is also a technological aspect that allows students to freely access various sources of learning information, allowing students to be more selective and proficient in obtaining information using various sources. This is the same as the opinion of Estapa & Tank (2017) that STEM is an effective way to provide and maintain the integration of science, technology, mathematics, and engineering. This follows Becker & Park's (2011) research which shows that STEM can impact learning outcomes in science and technology.

Applying learning with STEM learning is inseparable from a scientific approach. It can also be seen from the syntax performed by the student. In this case, the syntax used is a problem-based learning model. According to Kristiani et al. (2016), PBL is learning that requires students to solve problems through stages of scientific methods to gain knowledge about problems and develop problem-solving skills.

However, some students in this study still experienced an increase in learning outcomes with a very low category. Researchers' observations during the study showed that students with a low N-Gain category tended to be less active during the study. This follows Nabillah and Abadi (2020) that several factors affect students' low scores, including the lack of active participation in learning activities. It refers to the effective aspects experienced by students. According to Mardhiyatirrahmah et al. (2020), in addition to cognitive aspects, including affective aspects in applying STEM approaches, also have a positive effect. Therefore, when the emotional dimension or interest in learning outcomes. Another factor that causes low student learning outcomes is students' ignorance of learning activities using the STEM-PBL model and students' comprehension ability.

Here are some things to note and advice for teachers and other researchers to make learning activities more effective and improve learning outcomes when implementing STEM learning in the classroom. The ability to apply STEM learning to another learning model, the selection of material that can be related to existing STEM concepts. Sukmana (2018) states that this approach can create a cohesive learning system and active learning because these four aspects are needed simultaneously to solve problems. Proper supervision and guidance ensure students are actively involved in its implementation and can participate in using the learning structure provided so that students can absorb and understand the material well.

CONCLUSION

The conclusion of this study is STEM learning has a significant effect on student learning outcomes in class VIII at Samarinda, Indonesia. It is indicated by the average score of student learning outcomes obtained from 11.70 to 53.87, and the significance of the paired sample t-test with a significance (2-tailed) of 0.000, meaning less than 0.05, shows an influence on learning outcomes in STEM learning. Suggestions for further research are expected so that researchers can use other models to prepare for STEM learning and pay more attention to student behavior during learning.

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