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The Effect of STEAM Learning on Improving Each Indicator of Students' Creative Thinking in Physics Learning

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Abstract

The research aims to analyze the effectiveness toward which STEAM learning improves each indication of students' creative thinking ability in physics learning. This research used a quantitative approach with a quasi-experimental design and a non-equivalent pretest-posttest control group design. In this research, the Class XI science students of SMA Negeri 1 Mentaya Hilir Utara during the 2022-2023 school year would present as the population. Class XI IPA I was selected as the experimental class, while class XI IPA II was presented as the control class in the sample. The collected research data will be analyzed using the Willcoxon test, the Mann-Whitney difference test, and the N-gain test. The improvement (N-Gain) of all indicators has reached the moderate category. Indications in the element of elaboration increased the highest, while indicators in the aspect of originality increased the lowest. Based on the improvement in each indicator and the results of regression tests on each indicator, it is demonstrated that STEAM learning has a very favorable effect on students' creative thinking abilities. STEAM-based learning is recommended for usage as an innovation in physics learning in schools in order to develop creative thinking.

Keywords: Creative Thinking; Physics Learning; STEAM

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INTRODUCTION

In the 21st century, humans are required to have a variety of skills. In achieving these skills, flexibility is needed, as are being proficient in adapting, collaborating, thinking critically, being able to solve a problem, being able to innovate and be creative, being able to communicate well, understanding information literacy, media, and technology, having an attitude of leadership and responsibility, and being able to take the initiative, be productive, be accountable, and have cross-cultural social interactions. (Archambault et al., 2010; Fajri et al., 2020; Kendar & Vihar, 2020; Rayna & Striukova, 2021; van Laar et al., 2020). The demands of 21st-century abilities can be trained and developed through basic skills, one of which is creative thinking (Zubaidah, 2019).

In general, creative thinking is defined as the ability to develop unique solutions to a problem to produce something distinct

from previous solutions (Marliani, 2015). The four indicators of creative thinking are *fluency, flexibility, originality* and *elaboration* (Maharani, 2014). *Fluency* is providing alternative ideas, suggestions, and questions fluently. *Flexibility* is the ability to express thoughts or ideas from different perspectives. *Originality* is the ability to express ideas to solve problems by combining various elements in a common, unique, and new way that has never been thought of before. The skill of enriching, adding to, developing, describing, or detailing the details of objects, ideas, notions, and situations to make them more interesting is called *elaboration* skill (Aini, 2021)

In preliminary research conducted through a questionnaire filled out by 21 students of class XI IPA at SMA Negeri 1 Mentaya Hilir Utara, it was found that 57.14% of students experienced problems understanding the material in physics learning. Students think that the material in physics learning is too complicated and does not include examples of applications that are easy to understand. As many as 98.24% of students could not provide ideas different from most people who had not thought of them before, and 80.95% of students were not sure they could solve the exercise problems in various ways. This indicates that students' creative thinking skills are still low. Through the questionnaire data, it is found that students are only given physics theories through teacher-centered learning. This is the cause of the difficulty students have in providing new ideas for learning, causing low creative thinking skills (Panggabean et al., 2021). Implementing learning that can improve students' creative thinking skills can solve existing problems.

STEAM learning includes Science subjects with artistic elements (Mu'minah & Suryaningsingh, 2020). The STEAM approach to education can enhance students' creativity, expression, communication, imagination, observation, opinion, and thought, as well as their observation, problem-solving, matching, and decision-making abilities (Taylor, 2016). Through the STEAM approach, learners' skills in sharing ideas and ideas that are more creative can be honed and improved. Thus, learners' creativity and developing soft skills can be enhanced through collaborative activities and cooperation between groups and being critical of surrounding phenomena. (Hadinugrahaningsih et al., 2017). The STEAM approach offers an interesting and exciting method, making it more meaningful for students (Yakman & Lee Hyonyong, 2012).

There has been a lot of research on STEM, including literature on the application of STEM in physics. However, in this research, the components studied were only the elements of *science, technology, engineering,* and *mathematics*. The element of art is not included in the research (Norlaili et al., 2022). Research on the research of the application of STEAM to creative thinking skills in physics learning has also been carried out by several researchers. PJBL-STEAM learning through Spectra-Plus can increase students' creative thinking skills. (Lestari, 2021). Further research suggests that PjBL-based STEAM can improve students' creative thinking skills (Fitriyah & Ramadani, 2021). Other research discusses how implementing the STEAM-integrated PjBL learning model in chemistry can improve students' creative thinking skills and learning outcomes (Annisa et al., 2019; Rahman et al., 2019). Two previous studies that examined the effects of PBL and PjBL learning integrated with STEAM on students' creative thinking skills in terms of concept understanding found that creative thinking skills on fluency indicators obtained the highest increase compared to other indicators (Budiyono et al., 2020; Rohman et al., 2021). In previous research, there has been no research on STEAM implementation to determine the effect of each creative thinking indicator in physics learning. This research aims to determine how much influence STEAM learning has on students' creative thinking skills for each of the four creative thinking

indicators (fluency, flexibility, originality, and elaboration). The research data obtained is expected to be useful for producing interesting and innovative learning and has the opportunity to improve students' creative thinking skills.

METHOD

The research was conducted at SMA Negeri 1 Mentaya Hilir Utara in the 2022–2023 academic year. The research was conducted quantitatively using a quasi-experiment with a non-equivalent pretest-posttest control group research design. Students in grade XI IPA at SMA Negeri 1 Mentaya Hilir Utara in the 2022-2023 academic year were taken as the research population, while two classes were selected as experimental and control classes with certain considerations based on the sampling technique, namely purposive sampling. The instruments used in the study were lesson plans, student worksheets, and creative thinking ability test questions—as many as 24 description questions. The test questions are used to measure the level of creative thinking skills of students before and after treatment in the form of STEAM-based learning. Previously, the instruments used in the research were validated by three instrument experts. The validation criteria for the feasibility of the instruments used can be seen in Tables 1 and 2.

Table 1 Learning implementation design score criteria

Score Range	Criteria	Follow-up
$91 < x \leq 100$	Very Good	Feasible to use without revision
$76 < x \leq 91$	Good	Feasible to use with minor revision
$61 < x \leq 76$	Less	Not yet feasible to use in learning

Table 2 Score criteria for creative thinking ability test instruments

Score Range	Criteria	Follow-up
$80 < x \leq 100$	Very Good	Feasible to use without revision
$61 < x \leq 80$	Good	Feasible to use with minor revision
$41 < x \leq 60$	Less	Not yet feasible to use in learning

Based on the criteria in Table 1 and 2, the results of expert validation on the feasibility of learning implementation design instruments, student worksheets, and creative thinking ability test questions can be seen in Table 3 and 4.

Table 3 Results of instrument validation of lesson plans and learner worksheets

Research Instruments	Aspects	Validator	Criteria
Lesson Plans	Format	93.75	Feasible
	Content	88.75	
	Language	100	
Learner Worksheets	Format	95	Feasible
	Content	95	
	Language	100	

Table 4 Results of validation of creative thinking ability test instruments

Research Instrument	Aspects	Validator		Average	Criteria
		1	2		
Test	Content	94.75	96	95.38	Feasible
	Construction	95.5	95.75	95.63	
	Language	96	96	96.00	

Learning is carried out for three meetings after the learning instrument is declared feasible. The first meeting contained a pretest, learning, and project planning. The second meeting contained activities in the form of learning and

project-making. The last meeting contained data collection and processing activities, presentations, and posttests. The STEAM learning stages used in this study can be seen in Table 5.

Table 5 STEAM learning phases

Learning Phases	Learning activities
Problem identification/problem formulation phase	Learners will be given problems related to the material to be learned by containing elements of science.
Problem-solving design phase	Learners design a problem solution in the form of a project containing STEAM elements
Creating/making phase	Learners begin to create projects that load STEAM elements that have previously been designed
Project use phase	Learners use projects made under the supervision of educators by loading STEAM elements
Evaluation phase	Providing scaffolding to learners if some steps and stages are not correct when collecting and processing data by loading STEAM elements.
Communication and reflection phase	Present the data obtained, ask questions among students, and provide reflection to students by paying attention to STEAM elements.

From the learning stage, the implementation of the lesson plan in this study reached 100%. Data on students' creative thinking skills would be divided into each creative thinking indicator. The results of a description test of 24 items, assessed using a rubric for evaluating creative thinking skills, yield data on creative thinking skills. The increase in creative thinking skills would be seen from statistical tests using the Wilcoxon and Mann-Whitney difference tests, as well as the N-gain value on the pretest-posttest value for each indicator.

RESULTS AND DISCUSSION

The pretest and posttest data analysis and the Willxocon test results show that the experimental and control classes' creative thinking skills had the same significant value of 0.000. The results of the Willxocon test for creative thinking skills between the pretest and posttest of the experimental and control classes are shown in Table 6.

Table 6 Willxocom test results of creative thinking ability between *pretest* and *posttest*

Classes	Sig*	Description
Experiment	0.000	There is a difference between pretest and posttest scores
Control	0.000	There is a difference between pretest and posttest scores

Based on the results of the Willxocon test in Table 6, there was no difference in the results between the experimental and control classes because they both experienced an increase after the posttest. The difference between the experimental and control classes can be seen through the posttest value, which was tested using the Mann-Whitney test. The results of the Mann-Whitney test obtained a significance value of 0.000, which shows the difference between the experimental and control classes. The Mann-Whitney test results can be seen in Table 7.

Table 7 Mann-Whitney difference test table posttest value of creative thinking ability

Variable	Sig*	Description
Posttest	0,000	There was a difference between the experimental class and the control class

Based on Table 7, which uses a different test, the Mann-Whitney test, it can be seen that creative thinking skills, when viewed from the posttest data of the

experimental and control classes, obtained a significance value of 0.000. This shows a difference between classes that are not given STEAM-based learning and classes that are given STEAM-based learning. This finding is in line with previous research, which states that there are differences in posttest data in the control and experimental classes (Fitriyah & Ramadani, 2021).

Table 8 Regression test table of creative thinking ability for each indicator

Indicator	Sig*	Description
Fluency	0.018	Affected
Flexibility	0.000	Affected
Originality	0.000	Affected
Elaboration	0.065	Affected

Based on Table 8, the regression test showed the acquisition of significance values for each indicator of creative thinking in the experimental class. The fluency indicator received a significance value of 0.018 0.05, flexibility received a significance value of 0.000 0.05, originality received a significance value of 0.000, and elaboration received a significance value of 0.65 0.05, implying that STEAM-based learning influences each indicator of creative thinking.

Based on the results of the average pretest-posttest scores, the gain and N-gain of students' creative thinking skills in the experimental and control classes can be seen in Table 9.

Table 9 Mean score of pretest, posttest, gain and n-gain of creative thinking skills

Classes	Variable	Score	Criteria
Experiment	*Pretest*	35.76	Fair
	Posttest	68.70	
	Gain	32.94	
	N-gain	0.55	
Control	*Pretest*	35.90	Low
	Posttest	47.17	
	Gain	11.27	
	N-gain	0.19	

Table 9 shows the average pretest score of 32.76 and the posttest score of 68.70 in the experimental class on creative thinking skills. The acquisition of a gain value of 32.94 and an N-gain value of 0.55 in the moderate category shows an increase in students' creative thinking skills. As for the control class, the average pretest was 35.90, and the posttest was 47.17; this shows a slight increase in students' creative thinking skills with a gain of 11.27 and an N-gain of 0.19 in the low category. The findings on the average scores in the experimental and control classes were reinforced by previous research, which concluded that there was an effect of STEAM learning on students' creative thinking skills based on the acquisition of the average posttest scores of the experimental and control classes (Safriana et al., 2022)

Table 9 shows the creative thinking skills in the experimental class when reviewed on each creative thinking indicator. Creative thinking indicators in the elaboration aspect had the highest value results, with an N-gain score of 0.54 in a moderate category. The last increase occurred in the originality indicator, worth 0.47. In previous research conducted by Sri Lestari, the highest increase was obtained in the fluency indicator, while other aspects experienced a less massive increase (Lestari, 2021).

Table 10 Mean value of pretest, posttest, gain and n-gain of creative thinking skills of experimental class on each indicator

Indicator	Variable	Score	Criteria
Fluency	*Pretest*	52.41	Fair
	Posttest	73.55	
	Gain	21.14	
	N-gain	0.49	
Flexibility	*Pretest*	47.23	Fair
	Posttest	72.11	
	Gain	24.88	
	N-gain	0.51	
Originality	*Pretest*	26.75	Fair
	Posttest	59.37	
	Gain	32.62	
	N-gain	0.47	
Elaboration	*Pretest*	25.76	Fair
	Posttest	63.52	
	Gain	37.74	
	N-gain	0.54	

Elaboration is the creative thinking indicator that experienced the highest increase. In the fluency indicator, most of the tests done by students during the pretest can be answered by students. The answers were less varied, and some were not in accordance with the questions. The students' answers during the posttest were very diverse, and the level of understanding of the test questions on the fluency indicator was quite good. However, there were still incorrect answers from students. In the originality indicator, learners get poor results during the pretest. At the time of the posttest, students who gave better answers to questions were included in the originality indicator Meanwhile, the flexibility indicator revealed that many learners did not provide answers at the pretest. At the time of the posttest, students could answer the problems given even though they had not obtained the maximum score in some questions. Apart from elaboration, the other three indicators experienced a less-than-optimal increase, even though they were still in the medium category. The findings in the research are almost the same as those found in previous studies, where originality experienced the lowest increase while elaboration and flexibility indicators got the highest increase. (Rahman et al., 2019)

At the time of the pretest, the results can be illustrated in the students' answers as follows: Learners tend to be afraid and shy when it comes to sharing their ideas about the problems they are given. 2. In answering the questions, there was still a tendency for students to answer based on the usual working steps taught and not adjust for the context of the question. 3. This is because the problems in the problem could not be solved only with the working steps commonly used by teachers and students through known, asked, and answered patterns. Such patterns generally require a simple grouping of problem variables. Regarding creative thinking indicators, one and the other are inextricably linked. This finding is almost in line with previous research, which states that there is an increase in several aspects not fully seen in students' pretest and posttest answers (Lestari, 2021; Rahman et al., 2019).

Documentation of student project activities and experiments is shown in Figure 1.

Figure 1 Learners' project and experiment activities

In the experimental class, STEAM learning was used, which refers to the stages of project-based learning. The activities carried out by students are documented in Figure 1. The learning process includes problem identification, problem formulation, problem-solving design, project creation and implementation, evaluation, communication, and reflection. In the experimental class, learners met the demands to be creative in designing tools to solve problems. This is different from the activities in the control class, which used conventional learning. Activities in the experimental class could stimulate creative thinking skills so that, when given posttest questions, the results in the experimental class are better. This aligns with previous research that found an increase in posttest scores in classes that applied STEAM-based learning (Annisa et al., 2019). Understanding the existence of many variables and their complex relationships significantly impacts students' mindsets when solving problems in the test.

Research on the study of the application of STEAM to creative thinking skills in physics learning has also been carried out by several researchers. PJBL-STEAM learning through Spectra-Plus can increase students' creative thinking skills. The N-gain analysis of each creative thinking indicator, it shows that there is an increase in four aspects that fall into moderate criteria with a range of scores that are not much different. This implies that each indicator of creative thinking is linked to the others. When the learning implemented can improve creative thinking skills, the four indicators will also increase in the same range. The moderate category indicates that the learning has not been maximized. The most dominant inhibiting factor is that the learning carried out outside of this study has not referred to creative thinking skills. This study marks the beginning of the experimental class's participation in learning activities that promote creative thinking skills. Further research is needed to see the effect of STEAM learning on creative thinking skills. Previous research conducted by Lestari found an increase in three aspects, namely fluency, flexibility, and originality (Lestari, 2021); other studies found an increase in the same four aspects, namely fluency, flexibility, originality, and elaboration (Annisa et al., 2019; Rahman et al., 2019).

Based on the above analysis, STEAM-based learning has many advantages and can improve students' creative thinking skills, which are part of their 21st-century skills. This is in line with previous studies, which state that implementing STEAM in learning can train and develop students' skills and talents and improve their creative thinking skills (Annisa et al., 2019; Fitriyah & Ramadani, 2021; Lestari, 2021; Mu'minah & Suryaningsih, 2020; Rahman et al., 2019; Safriana et al., 2022).

CONCLUSION

From the analysis, it is known that STEAM-based learning is related, and influential, and can improve each indicator of students' creative thinking skills. The increase (N-Gain) of all indicators reached the medium category. Indicators in the elaboration aspect experienced the highest increase, and indicators in the originality aspect experienced the lowest increase. The effect given on each indicator is positive. STEAM-based learning is a recommendation for teachers to use as a physics learning innovation in schools to improve creative thinking skills.

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