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Improving Creative Thinking Skills through Integration of Problem-Based Learning with STEAM In Environmental Pollution Material

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Abstract: The 21st century demands today's students to face increasingly complex life problems and a globally rigorous work environment. A learning model that can facilitate learners in developing their creative thinking skills is necessary. The objective of this research is to determine the influence of PBL-STEAM integration on learners' creative thinking abilities in the topic of environmental pollution. This type of research is quantitative with quasi-experimental research methods. The research sample consisted of 58 learners, with each class consisting of 29 learners selected through simple random sampling. Based on hypothesis testing using independent t-test at $\alpha = 0.05$, the research findings showed a significance value of 0.00, this suggests that the PBL-STEAM learning model has an effect on learners' creative thinking in the topic of environmental pollution. The influence of the PBL-STEAM model on learners' creative thinking abilities can be analyzed based on the syntax of learning within the PBL-STEAM model. The results of this research imply that the PBL-STEAM learning model can be employed as a substitute for a model that enhances students' creative thinking abilities in the topic of environmental pollution.

Keywords: Creative Thinking Skills; Environmental Pollution; PBL; STEAM

Introduction

The 21st century demands today's students to face increasingly complex life problems and a globally rigorous work environment. In dealing with this situation students need to have a variety of strong thinking skills and various other skills known as 21st century skills (Zubaidah, 2019). One of the 21st century skills that students today need is the ability to think creatively (Zohar & Cohen, 2016).

Creative thinking can train students to develop many ideas and arguments, ask questions, and be responsive to different views (Sumarni & Kadarwati, 2020). With this ability, students will find many solutions to solve various challenges in their environment. As a result, students who lack the ability to think creatively will have a hard time finding alternative solutions to their problems (Sigit et al., 2019).

Students in Indonesia have the ability to think creatively which is included in the low category (Nurhamidah et al., 2018). This is in accordance with research conducted by the Martin Prosperity Institute (2015) in The Global Creativity Index which states that out of 139 countries, the Indonesian people's creativity index is in 115th position. The reason for the low ability of students' creative thinking is that the learning model applied in schools tends to be used by conventional learning models (Septiana & Ikhsan, 2017) and teachers are more active than students when learning takes place (Sihaloho et al., 2017). Therefore, an effort is needed to be able to optimize students' creative thinking abilities through the learning process.

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In order to enhance students' creative thinking, teachers must be able to create a creative classroom environment (Iskandar et al., 2020). The learning atmosphere needs to be designed in such a way that students can freely work to bring up various creative thoughts and ideas during the learning process (Üret & Ceylan, 2021). As such, a learning model is necessary that facilitates the development of creative thinking abilities in students. Problem Based Learning (PBL) is a teaching method that facilitates the development of creative thinking (Kusumawati et al., 2021).

In PBL, problems that are relevant to the real world are used as lesson contexts, this allows students to learn to think creatively in solving these problems so as to facilitate the acquisition of important knowledge and ideas from existing subject matter (Amrina et al., 2020). Creative thinking can indeed be trained through the PBL model, but the application of PBL alone is not enough. Another approach to learning is also necessary that promotes the greatest possible improvement in students' creative thinking abilities. One approach of this type is the STEAM approach (Ahmad et al., 2021; Budiyono et al., 2020; Hehakaya et al., 2022).

The application of PBL-STEAM can be done on environmental pollution material, this is to train students' thinking skills so they can find solutions to environmental damage that is happening at this time (Putri et al., 2018). In addition, environmental pollution material is a science learning topic that requires students to have high analytical skills (Azrai et al., 2017). In environmental pollution material, there are many environmental problems that can be identified and a solution is needed, one of which is the ability to think creatively.

Based on research conducted by Budiyono et al., (2020) It's recognized that the PBL-STEAM model has a significant impact on the creative thinking abilities of high school students. However, this research was conducted with only one experimental class that lacked a comparison class. Research by Hehakaya et al., (2022), The integration of PBL-STEAM in the ecosystem has an effect on high school students' creative thinking abilities. Next on research Ahmad et al., (2021) it is known that learning using the STEAM approach can develop creative thinking skills in semester 5 college students.

Based on the identification that has been described, research related to the PBL-STEAM model and its effect on junior high school students' creative thinking abilities on environmental pollution subject has never been done. On the basis of this explanation, this research aims to analyze the influence of the PBL-STEAM model on junior high school students' creative thinking abilities on environmental pollution.

Method

The quasi-experimental method was employed in this study and research design pretest-post-test non-equivalent group design. The participants were students of the 7th grade in a local high school in East Jakarta, Indonesia. Pretest and posttest data collection was carried out using a creative thinking ability test instrument which was compiled based on environmental pollution material and consisted of 18 essay questions. The instrument consists of 4 indicators of creative thinking which include fluency of thinking, flexibility of thinking, originality and elaboration (Munandar, 1999). Also employed in this investigation were learning observational instruments that were used to determine the degree to which learning was implemented in both classes. The observation of the implementation of learning (Riduwan, 2015) demonstrated in Table 1.

Table 1. Learning Implementation Percentage Category

Value (%)	Category
81 – 100	Very Good
61 – 80	Good
41 – 60	Enough
21 – 40	Bad
0 – 20	Very Bad

A total of 29 students in the experimental class and 29 students in the control class who were selected by simple random sampling method were the samples of this study.

The experimental class was facilitated by the PBL-STEAM model, and the control class was facilitated by the PBL model alone. Data analysis involves calculating the Normalized Gain Test to determine the increase in student scores in both classes and the degree to which the learning model is effective. The N-Gain value category (Hake, 1999) is evident in Table 2.

Table 2. Category of N-Gain Values

Value	Category
$g > 0.70$	High
$0.30 < g \leq 0.70$	Medium
$g \leq 0.30$	Low

The prerequisite test involves the normality test using the Kolmogorov-Smirnov test and the homogenity test using the F test with a p value (α) of 0.05. To assess the hypothesis via independent t-test analysis with a p value (α) of 0.05 using SPSS version 26.

Result and Discussion

The results of the students' creative thinking ability tests at the pre-test and post-test in the experimental and control classes are listed in Table 3.

Table 3. Value of Creative Thinking Ability in Experimental and Control Classes.

Data	Exp. Class		Control Class	
	Pretest	*Posttest*	*Pretest*	*Posttest*
Max. Score	37.50	70.83	51.38	54.16
Min. Score	80.55	93.05	81.94	90.27
Average	67.33	83.56	67.95	78.25
Std.	8.60	6.05	7.33	9.37
Sample				29

The results of the test indicated that the average degree of students' creative thinking abilities in both classes had increased. The increase in pretest and posttest scores can be seen in Figure 1.

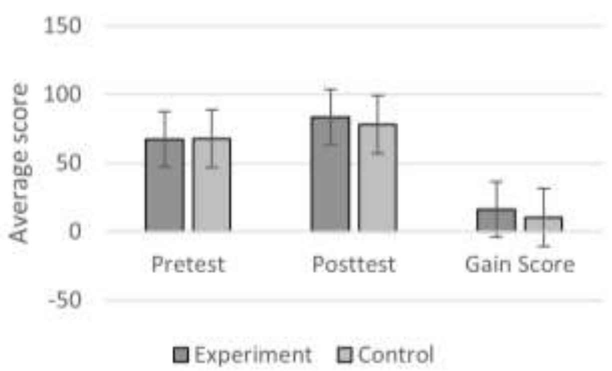

Figure 1. The increase in pretest and posttest scores

Table 4 illustrates the results of the Normalized Gain Test's calculations.

Table 4. Normalized Gain Test Results

Class	Gainscore	N-Gain	Category
Experiment	16.23	0.50	Medium
Control	10.29	0.33	Medium

Based on the data in Table 4, the gain score and n gain of the experimental class are greater than the control class, this implies that the PBL-STEAM model is more effective in increasing creative thinking skills than the control class, which is only taught with the PBL model. The outcomes of the calculations of the hypothesis test using the independent t-test on the gainscore of the experimental and control classes can be observed in Table 5.

The outcomes of the hypothesis test indicate that the PBL-STEAM model has an effect on students' creative thinking abilities. This is evident in Table 5. Where the significance value is (0.00) < α (0.05).

Table 5. Hypothesis test using independent t-test

Result	Normality	Homogenity	Sig. (2 *tailed*)	Note
Gain score	0.06>0.05	0.12>0.05	0.00	Sig.< 0.05

The observation of the implementation of learning was also conducted in this research. Observations are carried out by observers by referring to the Learning Implementation Observation Sheet which is prepared based on the syntax of the Lesson Plan. The results are exhibited in Table 6.

Table 6. Percentage of Learning Implementation

Subject	Class	Average Score (%)	Description
Teacher	Experiment	94.00	Very Good
	Control	90.60	Very Good
Students	Experiment	94.00	Very Good
	Control	89.90	Very Good

The results of the hypothesis test indicate that the PBL-STEAM model has an effect on students' creative thinking abilities on subject of environmental pollution. This concords with previous research that demonstrates the PBL-STEAM model has an effect on creative thinking abilities (Budiyono et al., 2020; Hehakaya et al., 2022).

The outcomes of the normalized gain test indicate that the experimental class has a higher average than the control class. This implies that the PBL-STEAM model in the experimental class is more effective in enhancing creative thinking abilities than the PBL model alone in the control class. These results are in line with research Hehakaya et al., (2022) that the PBL-STEAM model is effective for increasing students' creative thinking skills.

In the experimental class, the increase in the value of students' creative thinking skills is directly related to the PBL model's syntax., which is complemented by the STEAM approach. As stated by Blackley et al., (2018) that students can become more creative and innovative through learning that integrates the STEAM approach in it, this is because students are involved in exploring real challenges and problems. This is supported by El Sayary et al., (2015) who believe that the PBL-STEAM approach emphasizes critical thinking, creative thinking, and innovation. Having a creative process in the PBL-STEAM model can help increase student engagement and creativity, and enable teachers to present learning materials in new and innovative ways.

The enhancement of students' creative thinking abilities in the experimental classroom via PBL-STEAM can be deduced from the PBL model's syntax and every component of the STEAM approach. The initial syntax of PBL is the orientation of students to problems. At this stage, questions and answers are carried out related to environmental pollution problems to provoke students' curiosity and dig deeper into the issues to be discussed. Through this stage the ability to think fluently which is one aspect of students' ability to think creatively can be trained because they are given the opportunity to express the contents of their thoughts related to the problem to be discussed (Elizabeth & Dan Sigahitong, 2018). In addition, at this stage students' creative thinking skills can be developed through a process of connecting the material with the real-life problems discussed (Kartikasari & Widjajanti, 2017).

The second stage is organizing students to learn. The ability of students to collaborate can be developed at this stage through group problem solving activities (Arends, 2012). The discussion process that occurs between students and the teacher will make students share the information needed to solve problems, so that they can practice their flexibility in thinking, because at this stage they will look for many alternative solutions to problems with various approaches and different ways. In line with Jumadi (2018) who suggested that grouping students in this second stage could train students' ability to think fluently and think flexibly.

The next stage is to assist independent and group investigations. Students together with their groups explore various sources to find information that is useful in finding solutions to problems, such as the internet, books, or also through relevant videos (Azrai & Ristanto, 2020). At this stage students have the responsibility to elaborate information from various sources and choose the best approach as a solution to solving existing problems, as well as sparking new ideas based on information that has been previously explored. (Andersen & Rösiö, 2021). So that the ability to elaborate and think fluently can be trained in this third syntax.

The fourth stage is developing and presenting the results. At this stage students present the results of their discussions related to the issues discussed. Students learn to ask questions, create or enrich arguments, and also show many suggestions for doing something, so that their ability to think fluently, think flexibly, and elaborate them can be trained. In line with what was stated by Alfi et al., (2016) that presentation activities at this stage can develop students' creative thinking skills through asking, answering, and responding to the results of problem-solving discussions that have been carried out.

The final stage in PBL syntax is analyzing and evaluating problem solving activities. The teacher asks students to reflect on their thoughts and activities during the various stages of learning (Azrai & Ristanto, 2020). At this stage, students' Originality abilities can be trained because they learn to express their thoughts on things they have done themselves. In addition, students also learn to be aware of what things need to be known to be able to solve environmental pollution problems and the methods used to formulate solutions to solve these problems. (Hamdani et al., 2020).

In the PBL-STEAM model, the syntax used in PBL is combined with 5 elements of the STEAM approach which includes Science, Technology, Engineering, Arts, and Mathematics (Barrett, 2017; Katz-Buonincontro, 2018). The Science element in the PBL-STEAM model is found in almost all learning syntaxes. The science process skills used in the PBL-STEAM model enable students to hone their creative thinking skills through the process of constructing thoughts, generating questions, and finding solutions to a problem.

The technology element in the PBL-STEAM model allows students to investigate problems creatively and critically because currently most of the various information is available on the internet. This is in accordance with the opinion Nelson et al., (2011) that students will easily understand information accessed using the internet or various devices, besides that this can also improve the quality of learning. According to Kelley & Knowles (2016) the integration of technology as content provides an opportunity for students to think about the relationship between technology and the issues discussed, thereby preparing students for technology literacy. In addition, the use of technology as content allows students to practice their flexibility of thinking and original thinking through the process of connecting the benefits of technology with solutions to solve problems.

Meanwhile, the Engineering element is contained in the syntax of Assisting Independent and Group Investigations, as well as Developing and Presenting Results. At this stage students are directed to design a flow chart for solving environmental pollution problems. The process of designing this flowchart is a simple way to train students to use the Engineering Design Process (EDP) which is a characteristic of STEAM learning (Muttaqiin, 2023).

The Arts element in the STEAM approach can bring together various aspects of STEM through creativity. In line with opinion Yakman & Lee (2012) that science, technology, engineering, and mathematics will be more meaningful for students and make the learning process more enjoyable with the elements of creativity contained in art. In the PBL-STEAM model used in the experimental class, the element of art is in the fourth syntax, students are directed to present the results of their discussions related to problem solving in the form of infographic posters using the Canva editing software.

The last element in learning STEAM is Mathematics. At this stage students are directed to analyze and draw conclusions related to the environmental pollution quality index threshold. According to Taylor (2016) This process cannot be separated from mathematical elements because this problem-solving method uses various mathematical concepts, in the form of calculations, measurements, and comparisons. The use of elements of mathematics also allows students to practice the ability to think fluently through the process of calculating and comparing environmental pollution quality index thresholds.

As previously stated, can be observed that the PBL-STEAM model has a positive effect on enhancing students' creative thinking abilities. In addition, PBL-STEAM integration can also be used as an alternative way for teachers so that students can deal with the difficulties of the 21st century, because the process is related to 21st century abilities, namely creative thinking, collaboration, communication, and critical thinking. (Sari et al., 2022). As stated Suryanda et al., (2018) who argued that the 21st century the learning process must promote the capacity to think creative, critical, and have a strong reputation, as well as the capacity to utilize ICT.

Despite the fact that the PBL-STEAM model is more successful in increasing creative thinking abilities, the increase in creative thinking abilities also occurs in the control class using only the PBL model, as can be seen from the results of the gain scores in both classes. This increase is in agreement with research by Sihaloho et al., (2017) dan Wenno et al., (2021) that the PBL model has a significant impact on students' creative thinking abilities.

The process of implementing learning in teachers and students was also analyzed in this study through observation sheets. The outcomes of the analysis of the implementation of this learning are important in determining if the process of learning is properly or not (Azrai & Ristanto, 2020). The results as can be seen in Table 6 show that the percentage of learning implementation is in the range of ninety percent or in the very good category (Riduwan, 2015). This shows that overall, the implementation of learning in both the experimental and control classes have been carried out properly according to the stages of each applied learning model. This also shows that the data obtained in this study are objective because the learning process that takes place in both classes goes well and there is no tendency for the teacher to maximize the implementation of learning only in one particular class. (Istiani et al., 2018).

Developing students' creative thinking abilities is primarily a means of developing students' thinking processes in order to find solutions to various problems they have during the learning process and in their daily lives. Through each stage of the PBL model and each aspect of the STEAM approach, students have the opportunity to strengthen their creative thinking skills. The PBL-STEAM model places students in situations that require them to find solutions to given problems using methods that are appropriate to every aspect of STEAM learning. Consequently, students will be familiar with the creative processes that occur during learning so that their creative thinking skills can increase.

Conclusion

The results of the study indicate that the PBL-STEAM model of learning has an effect on students' creative thinking abilities on environmental pollution material. Students who learn using PBL and the STEAM approach have learning activities that can empower their creative thinking skills.

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Author Contributions

Ade Suryanda: Conceptualization, formal analysis, supervision, methodology, and writing review. Mieke Miarsyah: Validation, supervision, methodology, and writing review. Aby Hanhan Ulil Abshor Kosasih: Writing original draft, methodology, software, and editing.

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Conflicts of Interest

The authors deny there is any conflict of interest associated with this research.

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