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The Effect of the Science, Technology, Engineering, and Mathematics (STEM)-Based Problem-Based Learning (PBL) Model on Students' Creative Thinking Skills in the Topic of Heat in Grade XI at SMAN 1 Ngadiluwih

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ABSTRACT

Students are often trained to find a single correct answer rather than to develop various possible solutions to a problem. This study employed a quantitative approach with a Quasi-Experimental design, specifically the Posttest-Only Control Group Design. Data were collected through observation sheets, tests, and documentation. The data analysis techniques used consisted of Instrument Testing, Prerequisite Testing, and Hypothesis Testing. Based on the results of the study, it can be concluded that: 1) There is an effect of the Science, Technology, Engineering, and Mathematics (STEM)-based Problem-Based Learning (PBL) model on students' creative thinking skills, as indicated by the Mann-Whitney U test result with a significance value of 0.000 < 0.05. 2) The implementation of the STEM-based Problem-Based Learning (PBL) model effectively enhances students' creative thinking skills on the topic of heat. The results of learning in each aspect of creative thinking show that the application of this model can serve as an alternative solution to create active, meaningful, and challenging physics learning.

INTISARI

Siswa sering dilatih untuk menemukan satu jawaban yang benar dari pada mengembangkan berbagai kemungkinan solusi terhadap suatu masalah. Penelitian ini menggunakan pendekatan kuantitatif dengan desain Quasi Eksperimen jenis posttest Only Control Group Design. Pengumpulan data dilakukan melalui lembar observasi, tes, dan dokumentasi. Teknik analisis yang digunakan terdiri dari Uji Intrumen, Uji Prasyarat, dan Uji Hipotesis. Berdasarkan hasil penelitian, dapat disimpulkan bahwa: 1) Ada pengaruh model pembelajaran Problem-Based Learning (PBL) berbasis Science, Technology, Engineering, and Mathematics (STEM) terhadap kemampuan berpikir kreatif siswa, dengan hasil uji Mann Whitney U diperoleh nilai sig. 0,000 < 0,05. 2) Keterlaksanaan model Problem Based Learning (PBL) berbasis STEM terhadap kemampuan berpikir kreatif siswa pada materi kalor, dengan hasil pembelajaran pada setiap aspek kemampuan berpikir kreatif siswa penerapan model ini dapat

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menjadi solusi alternatif untuk menciptakan pembelajaran fisika yang aktif, bermakna, dan menantang.

A. Introduction

Creative thinking skills are one of the essential 21st-century competencies that students need to possess. These skills enable learners to generate diverse and original ideas and to solve problems from multiple perspectives. Unfortunately, physics learning in schools is still largely teacher-centered and outcome-oriented, which limits opportunities for fostering students' creativity [1].

Based on the results of observations and interviews with teachers at SMAN 1 Ngadiluwih, it was found that classroom learning often trains students to find a single correct answer rather than to develop multiple possible solutions to a problem. Students also lack the freedom to think broadly and creatively when responding to questions given by the teacher, particularly on the topic of heat. This condition has resulted in students' low creative thinking skills.

Problem-Based Learning (PBL) is a learning model designed to encourage students' active engagement in solving contextual problems. This aligns with the findings of Elizabeth & Sigahitong [2] in her study showed that the PBL model had a positive effect on students' creative thinking skills in learning static fluid material. The Science, Technology, Engineering, and Mathematics (STEM) approach is regarded as an effective strategy for promoting educational transformation in the 21st century [3]. This is in line with the findings of Aryani & Putri [4], whose research showed that the use of the Science, Technology, Engineering, and Mathematics (STEM)-based Problem-Based Learning (PBL) model had a significant effect on improving students' biology learning outcomes and their critical thinking skills in the topic of the immune system. This approach integrates various disciplines, allowing students to acquire knowledge and skills simultaneously. PBL helps students think critically, collaboratively, and creatively. When combined with the STEM approach, this model enables the integration of cross-disciplinary concepts to solve real-world problems [5].

The STEM-based PBL model has been proven effective in enhancing students' creative thinking skills [6]. There are various ways to integrate the STEM approach into the PBL model, one of which is through the use of teaching materials containing STEM contexts. These materials present problems related to real-world and interdisciplinary STEM contexts [7]. With this approach, students are not limited to solving physics problems alone but also draw upon knowledge from various STEM fields to find solutions [8]. Through this process, students gain new insights from multiple disciplines and are able to develop their thinking patterns in problem-solving [9]. This demonstrates that the implementation of a PBL model integrated with STEM in physics learning can enhance students' creative thinking skills [10].

The STEM approach is often used to encourage students to address various problems, including the development of creative thinking skills [11]. Based on this background, this study is entitled "The Effect of the Science, Technology, Engineering, and Mathematics (STEM)-Based Problem-Based Learning (PBL) Model on Students' Creative Thinking Skills in the Heat Topic for Grade XI at SMAN 1 Ngadiluwih, Kediri Regency" as a continuation of previous studies. This research aims to evaluate the effectiveness of the learning model in improving students' creative thinking skills.

B. Method

This study employed a quantitative approach using a quasi-experimental design with a post-test-only control group [12]. The research was conducted at SMAN 1 Ngadiluwih, Kediri Regency, during the even semester of the 2024/2025 academic year.

The population of this study consisted of all grade XI students, and the sample was determined using a purposive sampling technique. Class XI-2 was designated as the experimental class, where the STEM-based Problem-Based Learning (PBL) model was implemented, while Class XI-3 served as the control class, which was taught using conventional methods. Each class consisted of 35 and 36 students, respectively. The research was conducted by dividing the respondents into two groups: the experimental group and the control group. After the learning process, both groups were given post-test questions to determine the final condition and compare students' creative thinking skills between the experimental and control classes. The instrument used was a set of essay questions developed based on the indicators of creative thinking skills proposed by Munandar, namely: fluency, flexibility, originality, and elaboration [13].

The content validity was tested by expert lecturers and supervising teachers. The instrument was considered valid if it had a Pearson correlation value greater than 0.329. The reliability of the instrument was tested using the Cronbach's Alpha formula with the help of SPSS 30.0. Data analysis was conducted using the Kolmogorov-Smirnov test in SPSS 30.0 to examine the normality of the data. The decision criterion was that if the Sig value > 0.05, the data were considered normally distributed. Since the data were not normally distributed, the Mann-Whitney U test was used for hypothesis testing with the assistance of SPSS 30.0.

C. Result and Discussion

Before the instrument was used to collect data (distributed to respondents), the researcher first conducted an observation at the school to identify existing problems. Then, the researcher developed a set of instruments and conducted a series of instrument tests, beginning with expert validation.

The researcher sought assistance from a lecturer at UIN Sayyid Ali Rahmatullah Tulungagung to validate the instrument. Based on the results of the validation, the validator suggested that some questions should be removed, some should be added, and others should be revised in terms of wording and sentence structure. After the validator stated that the test instrument was feasible for trial, the questions were then tested on students who had already studied the topic of heat.

Table 1. Results of the Instrument Validity Test

Test	Pearson's r	t-statistic	r Table (N = 36)	Description
Item 1	0.435	2.816	0.329	Valid
Item 2	0.435	2.816	0.329	Valid
Item 3	0.737	6.358	0.329	Valid
Item 4	0.749	6.591	0.329	Valid
Item 5	0.656	5.067	0.329	Valid
Item 6	0.656	5.067	0.329	Valid
Item 7	0.345	2.143	0.329	Valid
Item 8	0.345	2.143	0.329	Valid

The table shows that the validity test results for the eight items indicate that all of them are valid. Each of the eight items has an $r_{calculated}$ value greater than the r_{table}. value. In addition, all items also have Pearson correlation coefficients greater than 0.329.

Table 2. Instrument Reliability Test Results

Correlation Coeficient	Criteria
$0.00 \leq r < 0.20$	Very low
$0.20 \leq r < 0.40$	Low
$0.40 \leq r < 0.60$	Moderate
$0.60 \leq r < 0.80$	High
$0.80 \leq r < 1.00$	Very high

Based on the results of the instrument reliability test for students' creative thinking skills administered to 36 respondents from class XII-1, the findings are as follows:

Table 3. Results of the Instrument Reliability Test

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.681	0.737	8

The table shows that the Cronbach's Alpha value is greater than 0.60, namely 0.681. Based on the reliability coefficient criteria, it can be concluded that all items

of the creative thinking skills test instrument used by the researcher fall within the category of moderate reliability.

Table 4. Results of the Normality Test

		Group	
		Control	**Eksperimen**
Kolmogorov-Smirnov[a]	Statistic	0.220	0.218
	df	36	35
	Sig.	0.000	0.000
Shapiro-Wilk	Statistic	0.908	0.916
	df	36	35
	Sig.	0.006	0.011

Based on the normality test results shown in the table, it can be seen that the significance value of the experimental class is 0.000 < 0.05; therefore, the data in the experimental class are not normally distributed.

Table 5. Results of the Homogeneity Test

Levene Statistic	**df1**	**df2**	**Sig.**
1.443	1	69	0.234

Based on the homogeneity test results shown in the table, it can be seen that the significance value of the experimental class is 0.234 > 0.05; therefore, the data in the experimental class are homogeneous. However, because the data are not normally distributed, the hypothesis testing was carried out using the Mann‑Whitney U test. The Mann-Whitney U test is a non-parametric alternative to the independent samples t-test, used to examine the differences between two independent groups when the data are measured on an ordinal or interval scale but not normally distributed. Therefore, this test is appropriate for analyzing the differences in students' creative thinking skills between the experimental group and the control group after the implementation of the STEM-based Problem-Based Learning (PBL) model.

Table 6. Results of the Non-Parametric Mann–Whitney U Test

	Value
Mann-Whitney U	67.500
Wilcoxon W	**733.500**
Z	-6.534
Asymp. Sig. (2-tailed)	**0.000**

Based on the results of the Mann–Whitney U test analysis, a significance value of 0.000 was obtained, which is lower than 0.05. This indicates that there is a

significant difference between the creative thinking skills of students in the experimental class and those in the control class.

Effect Size Cohen's d

The effectiveness test using Cohen's d is one of the methods used to evaluate the strength or effectiveness of a treatment in experimental research. Cohen's d provides a deeper interpretation of the significance test results, particularly in understanding the practical impact of the applied treatment [14]. The criteria for interpreting Cohen's d values are as follows:

d < 0.2 → the learning model has a low effect

d < 0.5 → the learning model has a moderate effect

d < 0.8 → the learning model has a high effect

Based on the analysis conducted, the following are the Cohen's d effect size results, which serve as indicators of the effectiveness level of the learning model.

	Control	**Experiment**
Mean	60.83	82.29
Standard deviation	11.180	8.166
Sample size (N)	36	35
Effect Size d_{Cohen} *resp.* g_{Hedges} *	2.187	
Common Language Effect Size *CLES***	0.939	

Based on the calculation using Cohen's d through the Psychometrica application, a value of 2.187 was obtained, indicating that the effectiveness of the STEM-based PBL model on the topic of heat falls into the high category according to Cohen's classification, which identifies the difference between the experimental group and the control group as highly significant. This value shows that the experimental class, with an average score of 82.29, performed significantly better than the control class, which had an average score of 60.83. The CLES value of 0.939 indicates a 93% probability that a student selected from the experimental class would score higher than a student from the control class.

Table 8. Descriptive Statistics of Students' Creative Thinking Skills Test

Statistic	Point	Class Eksperimen	Class Control
N	71	35	36
Minimum	35	60	35
Maximum	100	100	80
Mean	71.41	82.29	60.83
Standard deviation	14.545	8.166	11.180

Based on the table, the research results on creative thinking skills are as follows. The experimental class obtained a maximum score of 100 and a minimum score of 100, with an average test score of 82.29. The control class obtained a maximum score of 80 and a minimum score of 35, with an average score of 60.83. Across both classes, the maximum score was 100 and the minimum was 35, with an overall average test score of 71.41.

According to the assessment indicators of creative thinking skills [15]: Fluency: a score of 4 indicates that students correctly answered three or more questions on changes in heat; a score of 3 indicates correct answers for three questions; a score of 2 indicates correct answers for two questions; a score of 1 indicates one correct answer; and a score of 0 indicates no correct answer or an incorrect answer. Elaboration: a score of 4 indicates that students gave correct answers with four or more sentences detailing the response; a score of 3 indicates three sentences; a score of 2 indicates two sentences; a score of 1 indicates one sentence; and a score of 0 indicates no answer or an incorrect answer. Originality: a score of 4 represents responses given by 1%–4% of all students, a score of 3 represents 5%–9%, a score of 2 represents 10%–14%, and a score of 1 represents more than 19% of all students' answers. Flexibility: a score of 4 indicates that students provided four or more analytical factors; a score of 3 indicates three to four factors; a score of 2 indicates two to three factors; a score of 1 indicates one to two factors; and a score of 0 indicates no answer or an incorrect answer.

Based on the table of average scores for each aspect of creative thinking skills in the experimental class, originality and flexibility achieved the maximum average score of 4.00. Fluency had an average score of approximately 3.03, while elaboration had the lowest average score at around 1.71. The higher values of originality and flexibility indicate that originality reflects students' ability to generate unique and uncommon ideas, showing that they can think beyond usual patterns or conventional frameworks. Flexibility, on the other hand, demonstrates students' ability to produce a variety of ideas or solutions from different perspectives, signifying openness and adaptability in thinking. Thus, students with high originality and flexibility scores are typically able to solve problems in unconventional ways, not limited to a single

approach. They are creative in expressing opinions or creating something new, open to new ideas, and capable of adapting to various situations.

The lower scores in the aspects of fluency and elaboration compared to originality and flexibility indicate that students possess creative thinking potential but have not yet fully optimized their ability to develop and communicate their ideas. A low fluency score suggests that students are not yet able to generate a large number of ideas within a certain period, even though the ideas they produce may be unique (original). This means that the quantity of ideas remains limited. Meanwhile, a low elaboration score implies that students are less detailed in developing their ideas, resulting in thoughts that are not deeply expanded or lack specificity in explanation and application. Such students are able to think creatively in unique and flexible ways but still need to be trained to: Generate a greater number of ideas (increase quantity), and Develop ideas in a more detailed and applicable manner. This may indicate that students have a high creative potential but are not yet accustomed to expressing it comprehensively. They require additional stimulation or practice in articulating and expanding their ideas, as they are still in the early stages of developing holistic creative thinking skills.

Based on the table of average scores for each aspect of creative thinking skills in the control class, originality obtained an average score of 2.11, flexibility obtained an average score of 3.47, fluency had an average of 2.89, and elaboration had the lowest average at approximately 1.56. These findings indicate that students show a strong tendency toward creative thinking in terms of flexibility, reflecting their ability to generate various ideas from different perspectives. However, the relatively lower level of originality suggests that the ideas produced are still less unique or do not fully demonstrate original thought. Meanwhile, fluency falls within the medium category, meaning that students are able to produce several ideas, though not yet in an optimal quantity. Elaboration, which obtained the lowest score, indicates that students have difficulty developing, detailing, and expanding their ideas in a more in-depth and structured manner. Overall, it can be concluded that students possess potential in creative thinking—particularly in the flexibility of ideas—but they still need further encouragement and training to improve their ability to generate more ideas (fluency), create more unique ideas (originality), and develop ideas into more complex and detailed forms (elaboration). The results also show that the experimental class demonstrated higher performance in creative thinking skills compared to the control class. This is evident from the average score of the experimental class (82.29), which was higher than that of the control class (60.83), with all students in the experimental class achieving a perfect score (100). Meanwhile, the control class showed greater variation, with scores ranging from 35 to 80. These results indicate that the treatment or intervention applied in the experimental class had a significant effect on improving students' creative thinking skills. This improvement is reflected not only in the higher

average scores but also in the consistency of the experimental class, where all students achieved maximum results. The average creative thinking score of students in the experimental class was higher than that of the control class, with improvements observed across all aspects of creative thinking—fluency, flexibility, originality, and elaboration. This demonstrates that the STEM-based Problem-Based Learning (PBL) model is effective in enhancing creative thinking skills.

Based on the effectiveness calculation using Cohen's d through the Psychometrica application, the obtained value of d = 2.187 falls into the high category according to Cohen's classification, indicating that the STEM-based PBL model had a very large effect on improving students' creative thinking skills.

This result is further supported by the comparison of average scores between the two groups, where the experimental class achieved an average score of 82.29, while the control class obtained only 60.83. The considerable difference between these averages signifies a significant impact of the STEM-based PBL model on students' learning outcomes, particularly in the aspect of creative thinking in the topic of heat.

Additionally, the Common Language Effect Size (CLES) calculation produced a value of 0.939, meaning there is a 93% probability that a randomly selected student from the experimental class will have a higher score than a student from the control class. This further reinforces the evidence that the STEM-based PBL model is highly effective in enhancing students' creative thinking abilities.

In conclusion, the use of the STEM-based Problem-Based Learning (PBL) model has proven to be effective and highly impactful in improving students' creative thinking skills in the topic of heat. This model not only encourages students to actively solve real-world contextual problems but also integrates science, technology, engineering, and mathematics concepts in a unified manner, thereby fostering the development of higher-order thinking skills, including creative thinking.

D. Conclusion

There is a significant effect of applying the Problem-Based Learning (PBL) model based on Science, Technology, Engineering, and Mathematics (STEM) on students' creative thinking skills regarding the topic of heat. Based on the Mann–Whitney U test, the obtained Asymp. Sig value was 0.000. Since the value ≤ 0.05, H_0 was rejected and Ha was accepted. This indicates that students' creative thinking skills in the experimental class were higher than those in the control class. Therefore, the research hypothesis stating that "There is an effect of the STEM-based PBL model on students' creative thinking skills on heat material" is accepted.

The STEM-based Problem-Based Learning model was proven to be effective in improving students' creative thinking skills. The effectiveness test using Cohen's d obtained a value of 2.187, which falls into the high category, indicating that the model had a very strong influence on improving creative thinking skills. In addition, the Common Language Effect Size (CLES) analysis resulted in a value of 0.939, meaning

that there is a 93% probability that a randomly selected student from the experimental class would have a higher score than a student from the control class.

Based on these findings, it is recommended that physics teachers adopt and adapt the STEM-based Problem-Based Learning model in their teaching practices, particularly for topics that require problem-solving and creative thinking skills, such as the concept of heat.

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