The Effect of Problem-Based Learning (PBL) Model with a Multimodal Approach on Students' Physics Creativity

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Abstract - *This study investigates the effect of the Problem-Based Learning (PBL) model integrated with a multimodal approach on students' physics creativity. A quasi-experimental method was employed using a nonequivalent control group design. The study was conducted at SMAN 3 Praya during the even semester of the 2025/2026 academic year, focusing on the topic of static fluids. The participants were 54 Grade XI students selected through purposive sampling, comprising 26 students in the experimental class (XI F1) and 28 students in the control class (XI F2). Data were collected using a creativity test consisting of four essay questions designed to assess four dimensions of creativity: fluency, flexibility, originality, and elaboration. The data were analyzed using an independent-samples t-test with the pooled-variance formula. The results indicated a statistically significant effect of the PBL model integrated with a multimodal approach on students' physics creativity. The obtained t-value of 2.816 exceeded the critical t-value of 2.007 at the 5% significance level. Furthermore, the experimental class achieved a higher mean posttest score (74.81) than the control class (63.75). The N-gain analysis showed a moderate improvement in both the experimental class (0.652) and the control class (0.474), with greater improvement observed in the experimental class. These findings suggest that integrating a multimodal approach into PBL can enhance students' physics creativity and may provide an effective instructional strategy for supporting creative thinking in physics learning.*

Keywords: *Creativity; Multimodal Approach; Problem-Based Learning*

INTRODUCTION

Education plays a strategic role in preparing individuals who can think critically, communicate, collaborate, and create, the four competencies known as 4C skills essential for facing 21st-century challenges (Malikah & Wafroturrohmah, 2022; Mantau & Talango, 2023). Among these, creativity is an important ability to develop in physics learning, since physics requires students not only to master concepts but also to generate new ideas and unconventional solutions.

Creativity refers to an individual's ability to produce new, original, and useful ideas or solutions. Guilford (1967) was among the first to relate creativity to divergent thinking, generating various possible answers rather than the single correct answer of convergent thinking. Munandar (2009) added that creativity is the ability to form new combinations from existing data or elements, and can be trained rather than being purely innate. Building on this, Torrance (1974) operationalized creativity into four measurable indicators, fluency, flexibility, originality, and elaboration, widely used to assess creative thinking in physics education. This is consistent with Runco and Jaeger (2012), who argued that a genuinely creative response must be both novel and effective.

In practice, students' creativity in physics learning is still relatively low. Observations and interviews with the physics teacher at SMAN 3 Praya showed that learning in class XI is still dominated by conventional methods, with limited problem-solving activities, restricted laboratory practice, and minimal use of technology-based media. As a result, students have few opportunities to generate alternative ideas, view problems from different perspectives, or elaborate their

solutions, so their creativity has not developed optimally.

One alternative to address this problem is the Problem-Based Learning (PBL) model, which places students at the center of learning through investigating authentic and contextual problems, encouraging them to explore various possible solutions rather than a single correct answer. Ismawati et al. (2024) proved that PBL improves students' creativity by encouraging active involvement in idea exploration and independent problem solving. Putri et al. (2024) similarly found that PBL enhances creativity through active involvement in problem solving and idea development, while Ulfa et al. (2024) demonstrated that project-based learning, sharing PBL's emphasis on authentic and student-driven tasks, also significantly increased students' physics creativity.

The effectiveness of PBL in developing creativity can be further strengthened through a multimodal approach, which combines modes of representation such as text, images, video, and simulation to present information through more than one channel, giving students richer sources of inspiration for expressing their understanding creatively (Gunawan et al., 2025). Aisyah et al. (2024) reported that PBL assisted by PhET media strengthened students' critical thinking skills, suggesting that simulation-based media can support the cognitive processes underlying creative thinking. Simanjuntak et al. (2021) found that PBL combined with computer simulation was more effective in developing creative thinking than conventional learning, while Wiyarsi et al. (2018) proved that a multiple representation approach significantly affects students' creative thinking. Amrullah et al. (2026) further confirmed that a multimodal approach integrated into a learning model significantly improves the creativity of grade XI students, regardless of the specific learning model applied.

Based on the gap between the expected competency and the actual condition of students' creativity at SMAN 3 Praya, as well as the potential synergy between PBL and the multimodal approach in facilitating divergent thinking, this study aims to examine the effect of the Problem-Based Learning (PBL) model with a multimodal approach on students' physics creativity.

RESEARCH METHODS

This study employed a quasi-experimental method with a nonequivalent control group design (Sugiyono, 2023), involving two groups: an experimental class that received the PBL model with a multimodal approach, and a control class that received conventional learning.

The study was conducted at SMAN 3 Praya in class XI during the even semester of the 2025/2026 academic year, covering the topic of static fluid. The population consisted of class XI F1 and XI F2, totaling 65 students. Purposive sampling was used because not all classes in the school took the physics subject, so that the sample was determined based on the equivalence of the two classes in terms of curriculum, learning facilities, and teacher. Based on this consideration, class XI F1 was selected as the experimental class and class XI F2 as the control class. Of the 65 students in the population, 11 were excluded from the analysis because they were absent for either the pretest or the posttest and therefore did not have complete data, leaving 26 students in the experimental class and 28 students in the control class.

The independent variable was the PBL model with a multimodal approach, while the dependent variable was students' physics creativity. The research instrument was a creativity test consisting of 4 essay questions, each measuring one indicator of

divergent thinking according to Torrance (1974), namely fluency, flexibility, originality, and elaboration. Each item was scored using a rubric with a scale of 0-5. Data were collected through a pretest before treatment and a posttest after treatment.

Each modality was deliberately integrated into a specific stage of the PBL syntax rather than used as separate supplementary media, ranging from video, image, and narration at the problem orientation stage, to PhET simulation during investigation, tables/graphs with oral presentation at the results stage, and oral–written reflection during the final evaluation stage. The full mapping between each PBL phase and its corresponding modality is presented in Table 1.

Table 1. Integration Matrix of Multimodal Modes within the PBL Syntax

PBL Syntax Phase	Modality Integrated	Description of Activity
Problem orientation	Video, Image & Narration	Short videos and contextual images of real static-fluid phenomena were presented, accompanied by narration, to stimulate students' initial questions and hypotheses.
Organizing students to learn	Text, Image & Links within the LKPD	Structured worksheets (LKPD) containing step-by-step instructions for the PhET simulation, complete with images and simulation links, along with an answer sheet for students to record their work.
Guiding individual and group investigation	PhET Simulation	Students manipulated variables in PhET simulations and observed the resulting phenomena directly.
Developing and presenting results	Table/Graph & Oral Presentation	Students presented their findings orally in front of the class, using tables and graphs written on the whiteboard to communicate and justify the reasoning behind their solutions.
Analyzing and evaluating the problem-solving process	Oral & Written Reflection	Students compared results across groups, formulated conclusions collaboratively, and answered reflection questions in writing before sharing them orally.

Prior to use, the instrument was tested for validity, reliability, difficulty level, and discriminating power. Data analysis used prerequisite tests, namely the normality test (chi-square) and the homogeneity test (F-test), followed by hypothesis testing using the independent sample t-test with the pooled variance formula at a 5% significance level ($\alpha = 0.05$) since the two groups had unequal sample sizes. The N-Gain test (Hake, 1998) was also used to determine the extent of the increase in students' creativity after treatment, both overall and for each creativity indicator.

RESULTS AND DISCUSSION

This section presents the results of the instrument test, the description of creativity data, the prerequisite analysis tests, the hypothesis test, and the N-Gain test.

Results

1. Instrument Test

Table 2. Creativity Instrument Test Results

No.	Validity			Reliability			Difficulty level		Discriminating power		Conclusion
	r_{table}	r_{xy}	Desc.	r_{table}	r_{xy}	Desc.	TK	Desc.	DP	Desc.	
1	0.374	0.704	Valid	0.374	0.853	Reliable	0.562	Moderate	0.285	Fair	Revised
2	0.374	0.931	Valid	0.374	0.853	Reliable	0.466	Moderate	0.528	Good	Accepted
3	0.374	0.890	Valid	0.374	0.853	Reliable	0.481	Moderate	0.457	Good	Accepted
4	0.374	0.898	Valid	0.374	0.853	Reliable	0.511	Moderate	0.585	Good	Accepted

Table 2 shows that all four items of the creativity test were declared valid, with validity coefficients ranging from 0.704 to 0.931, exceeding r_{table} of 0.374. The reliability coefficient reached 0.853, which is categorized as very reliable. In terms of difficulty level, all items fell into the moderate category, with values ranging from 0.466 to 0.562, while the discriminating power ranged from 0.285 (fair) to 0.585 (good). Item 1 was revised because of its fair discriminating power, while items 2, 3, and 4 were accepted and used directly in the research instrument.

2. Creativity Data Description

Based on the data description, both classes started from a comparable initial condition, with a mean pretest score of 30.58 for the experimental class and 30.18 for the control class. After the learning process, the mean posttest score of the experimental class increased to 74.81, higher than the control class which reached 63.75, as illustrated in Figure 1.

Figure 1 shows that although both classes exhibited an increase in creativity from pretest to posttest, the improvement in the experimental class was considerably greater than that of the control class. This indicates that problem-solving activities supported by a multimodal approach were more effective in stimulating students' divergent thinking compared to conventional learning.

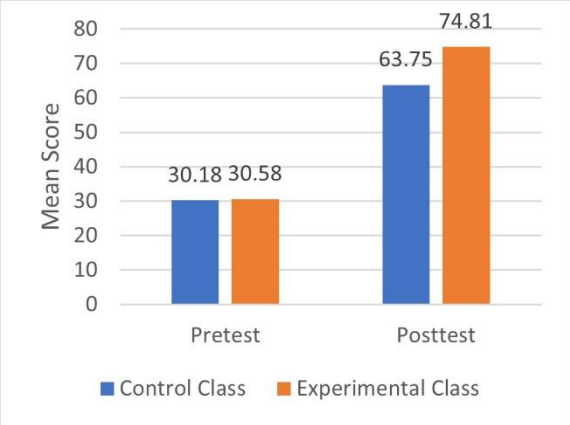


Figure 1. Comparison of Mean Creativity Scores between the Two Classes

3. Prerequisite Analysis Tests

Table 3 shows that all χ^2calculated values for both classes, both at pretest and posttest, were smaller than χ^2table of 7.815, so the creativity data of both classes were normally distributed.

Table 4 shows that the $F_{calculated}$ values for both the experimental and control classes were smaller than F_{table}, so the creativity data of both classes were homogeneous. Since both the normality and homogeneity requirements were met, hypothesis testing could proceed using parametric statistics.

Table 3. Creativity Normality Test Results

Group	Data	χ^2calculated	χ^2table (α = 0.050)	Description
Experimental	Pretest	2.906	7.815	Normal
Experimental	Posttest	6.917	7.815	Normal
Control	Pretest	7.575	7.815	Normal
Control	Posttest	7.738	7.815	Normal

Table 4. Creativity Homogeneity Test Results

Group	Variance (Pretest)	Variance (Posttest)	$F_{calculated}$	F_{table}	Description
Experimental	126.654	200.961	1.587	1.955	Homogeneous
Control	239.782	214.120	1.119	1.905	Homogeneous

4. Hypothesis Test Results

Hypothesis testing used the independent sample t-test with the pooled variance formula, since the posttest data of both classes were normally distributed, homogeneous, and had unequal sample sizes

(n1 = 26, n2 = 28). Table 5 shows that $t_{calculated}$ of 2.816 was greater than t_{table} of 2.007 at a 5% significance level with degrees of freedom (df) = n1 + n2 − 2 = 52. Based on the hypothesis testing criteria, since $t_{calculated} \geq t_{table}$, Ha was accepted and H0 was rejected, indicating that the PBL model with a multimodal approach had a significant effect on students' physics creativity.

Table 5. Hypothesis Test Results (Independent Sample t-test)

Group	Number of Students (n)	Mean	Variance (s^2)	$t_{calculated}$	t_{table}
Experimental	26	74.81	200.96	2.816	2.007
Control	28	63.75	214.12		

5. N-Gain Test Results

Table 6. N-Gain Score of Creativity

Group	Maximum Score	Minimum Score	N-Gain	Category
Experimental	92	27	0.652	Moderate
Control	91	13	0.474	Moderate

Table 6 shows that the experimental class achieved an N-Gain score of 0.652, which falls into the moderate category, while the control class achieved 0.474, also in the moderate category. Although both classes were in the same category, the increase in the experimental class was greater than that of the control class, confirming that the PBL model with a multimodal approach was more effective in developing students' creativity. A more detailed picture based on each creativity indicator is presented in Table 7.

Table 7. N-Gain Score of Creativity per Indicator

Indicator	Experimental class				Control class			
	Pretest	*Posttest*	N-Gain	Category	*Pretest*	*Posttest*	N-Gain	Category
Fluency	41.538	83.846	0.724	High	27.857	65.714	0.525	Moderate
Flexibility	43.077	79.231	0.635	Moderate	37.143	68.571	0.500	Moderate
Originality	23.846	68.462	0.586	Moderate	33.571	61.429	0.419	Moderate
Elaboration	13.846	67.692	0.625	Moderate	22.143	59.286	0.477	Moderate

Table 7 shows that in the experimental class, the highest increase was achieved by the fluency indicator (N-Gain = 0.724, high category), while the lowest increase among the four indicators was originality (N-Gain = 0.586, moderate category). In the control class, all indicators remained in the moderate category, with fluency again showing the highest increase (N-Gain = 0.525) and originality the lowest (N-Gain = 0.419).

Discussion

The results showed that the application of the PBL model with a multimodal approach had a positive effect on students' physics creativity. The mean pretest score of the experimental class was 30.58 and that of the control class was 30.18. After treatment, the mean posttest score of the experimental class increased to 74.81, while the control class reached 63.75. This difference was confirmed by the independent sample t-test with pooled variance, which produced $t_{calculated}$ of 2.816, greater than t_{table} of 2.007 at a 5% significance level. This finding is in line with Ismawati et al. (2024), who proved that PBL is effective in improving students' creative thinking ability

because it encourages active involvement in idea exploration and independent problem solving. Putri et al. (2024) similarly found that PBL improves students' creativity by providing opportunities to be actively involved in the process of problem solving and idea development, while Amrullah et al. (2026) proved that a multimodal approach integrated into a learning model significantly improves the creativity of grade XI students.

The development of students' creativity can be explained through the four indicators observed during the learning process, namely fluency, flexibility, originality, and elaboration. Fluency was reflected when students produced various alternative explanations for physical phenomena; flexibility appeared when students viewed a problem from more than one point of view and proposed more than one possible solution; originality emerged from ideas that differed from those of other groups; and elaboration developed as students detailed and strengthened their arguments through discussion and presentation. The development of these four aspects indicates that students were trained to think divergently, since they were not directed toward a single correct answer but were given the opportunity to explore various alternative solutions. Kosim et al. (2019) found that students' creativity in physics can be developed through these four aspects simultaneously through learning that encourages the use of various representations. Dewi et al. (2017) proved that a PBL model assisted by virtual simulation had a significant effect on students' physics creativity, indicating that problem-based learning supported by interactive media is able to optimize all four aspects of creativity. Hermansyah et al. (2015) also found that the use of a virtual laboratory had a positive effect on students' creative thinking ability, since visualization-based media are able to stimulate creativity in physics learning. Zulfaniar et al. (2024) likewise noted that well-designed physics teaching materials can enhance all major indicators of creative thinking simultaneously, underscoring the importance of instructional design alongside the choice of learning model.

The multimodal approach integrated into every stage of PBL also contributed to the development of students' creativity. The use of various representations, such as images, videos, tables/graphs, and PhET simulations, provided a richer learning experience, so that students were encouraged to understand physical phenomena from various points of view while developing more diverse ideas and solutions. At the problem orientation stage, exposure to contextual phenomena encouraged students to propose various initial hypotheses; at the investigation stage, the freedom to determine a problem-solving strategy encouraged divergent thinking; and at the stage of presenting results, students were not only required to obtain the correct answer but also to explain the reasoning underlying the solution they chose, so that the aspects of originality and elaboration developed further. Gunawan et al. (2025) emphasized that a multimodal approach in various science learning models has been proven to create a richer learning experience, thereby encouraging active engagement and creativity simultaneously. Simanjuntak et al. (2021) found that problem-based learning combined with computer simulation gave students broader opportunities to produce diverse solutions and products than conventional learning, while Wiyarsi et al. (2018) proved that a multiple representation approach has a significant effect on students' creative thinking ability. Comparable results were reported by Liana et al. (2023) and Widiarta et al. (2023), who found that PhET-assisted PBL improved students' problem-solving and critical thinking skills

respectively, indicating that interactive simulations help learners generate and evaluate a wider range of possible solutions.

The increase in creativity in the control class was not as high as that in the experimental class, since teacher-centered learning through lectures and question-and-answer sessions provided more limited opportunities for students to develop ideas independently, and tended to direct students toward predetermined answers, thereby narrowing the space for exploring alternative solutions. As a result, the development of the fluency, flexibility, originality, and elaboration indicators was not as optimal as in students who followed the PBL model with a multimodal approach. This finding is supported by Kosim et al. (2019), who found that students' creativity in physics develops optimally through learning that encourages the use of various representations and provides room to explore various possible solutions.

Further analysis showed that the four indicators developed differently depending on the learning activities involved. Fluency increased the most (N-Gain = 0.724, high category), since nearly every stage of the PBL syntax required students to generate more than one idea at once, a habit reinforced through repeated PhET simulation activities across the three meetings. Flexibility (N-Gain = 0.635) and elaboration (N-Gain = 0.625) also increased fairly well, as students were repeatedly trained to view phenomena from more than one perspective and to justify their solutions with structured reasoning in worksheets and presentations.

In contrast, originality recorded the lowest increase among the four indicators (N-Gain = 0.586), since most learning activities across the three meetings followed a fairly structured pattern with a clear direction toward correct answers, leaving students fewer opportunities to practice genuinely novel explanations before this was tested directly in the posttest.

Viewed from a cognitive perspective, the contrast between fluency and originality reflects the different mental demands of each process. Fluency (N-Gain = 0.724) was the easiest indicator to develop because the repeated, hands-on manipulation of variables in the PhET simulations allowed students to generate many ideas quickly through direct trial-and-error observation, a relatively low-demand associative process. Originality, in contrast, was the most difficult to develop because producing a genuinely unique idea in physics requires a mature and well-integrated understanding of the static fluid concept itself, a higher-order cognitive demand that most students had not yet reached after only three meetings of instruction. This distinction suggests that future worksheet (LKPD) designs should move beyond guided, single-answer tasks and explicitly adopt Open-Ended Problem formats, which require students to construct their own problem-solving pathways and are therefore more likely to stimulate the originality indicator.

It should be honestly acknowledged that the three-meeting intervention period, while sufficient to raise average scores, was relatively short for cultivating originality, a creativity indicator that typically requires repeated and less-guided opportunities to generate genuinely novel ideas. A longer treatment duration would likely give students more room to move beyond structured problem-solving patterns and to develop more original responses, and this limitation should be taken into account when interpreting the comparatively modest N-Gain observed for this indicator.

Based on the results of the data analysis and discussion, it can be concluded that the PBL model with a multimodal approach has a significant effect on students' physics creativity.

CONCLUSION

Based on the findings and discussion, it can be concluded that the Problem-Based Learning (PBL) model integrated with a multimodal approach had a significant effect on the physics creativity of Grade XI students at SMAN 3 Praya in learning static fluids. This finding is supported by the independent-samples *t*-test, which yielded a calculated *t*-value of 2.816, exceeding the critical *t*-value of 2.007 at the 5% significance level ($df = 52$). The experimental class also demonstrated a higher mean posttest score (74.81) than the control class (63.75), as well as greater improvement based on the N-gain score (0.652) compared with the control class (0.474), although both were categorized as moderate.

The implementation of PBL through authentic problem-solving activities, combined with multimodal representations such as videos, images, tables, graphs, and PhET simulations, supported the development of the four dimensions of creativity: fluency, flexibility, originality, and elaboration. However, originality showed comparatively slower development, indicating the need for more explicit learning activities that encourage students to generate novel and distinctive solutions.

Therefore, the integration of a multimodal approach into PBL can be considered a potential instructional strategy for fostering students' creativity in physics learning. Teachers are encouraged to incorporate diverse representations and authentic problem-solving activities into PBL, while future research should consider longer intervention periods and more targeted activities to strengthen students' originality.

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