The impact of Project Based Learning (PjBL) on creativity, critical thinking skills, and science learning outcomes of grade 7 student

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Abstract
This study is a quantitative research that aims to: (1) examine the influence of the Project-Based Learning (PjBL) model on students' creativity, (2) examine the influence of the Project-Based Learning (PjBL) model on student's' critical thinking skills, and (3) examine the influence of the Project-Based Learning (PjBL) model on students' psychomotor learning outcomes. This study adopted a pretest-posttest control group design involving seventh-grade students at junior high school in Surakarta as study population. Data collection techniques included pretest and posttest, questionnaires, observations, and interviews. Prerequisite tests included validity test, homogeneity tests, and normality tests. Hypothesis testing was conducted using the independent sample t-test and the Mann-Whitney test. The results of the study are as follows: (1) there was no significant influence of the PjBL model on students' creativity, with a sig. (2-tailed) value of 0.384 > 0.05 and the average observation score of the experimental class was 69.33, which was lower than that of the control class, 78.92. (2) there was a significant influence of the PjBL model on students' critical thinking skills, with sig. (2-tailed) values of 0.000 < 0.05 and 0.001 < 0.05. (3) there was significant influence of the PjBL model on students' learning outcomes, with a sig. (2-tailed) value of 0.007 < 0.05 and the average observation score of the experimental class was 78,49, which was higher than that of the control class, 73.93.

1. Introduction

Natural science is one of the branches of science that draws upon disciplines from both the natural and social sciences (Anggraini et al., 2019). In the process of learning science, creativity and critical thinking skills are essential. Many science topics encourage students to imagine and think critically. For instance, in the topic of substances and their changes, students are invited to visualize how changes in materials occur and to think about how one substance can transform into another.

Law of the Republic Indonesia Number 20 of 2003 on National Education System, defines education as "*a conscious and deliberate effort to create a learning environtment and process in which students actively develop their potential to acquire spiritual strength, self-control, personality, intelligence, noble character, and the skills necessary for themselves, society, the nation, and the state.*" In the context of IPA learning process, students have the opportunity to nurture their potential and develop essential skills through the practices of creative and critical thinking.

The Project-Based Learning (PjBL) model is an instructional approach that emphasize learning through project-oriented activites. According to Shin (2018), Project-based Learning helps students develop creativity, enhance motivation, intrinsic interest, collaboration, and problem-solving skills. The usage of the PjBL model encourage students to think creatively and critically while designing their projects. According to the George Lucas Educational Foundation (2005, as cited in Dinda and Sukma, 2021). The PjBL syntax includes the following stages: (1) starting with an essential question, (2) designing a project plan, (3) creating a project schedule, (4) producing the project, (5) assessment, and (6) evaluation.

Creativity is essential for both students and teachers. According to Torrance, creativity is a process in which individuals develop the ability to recognize obstacles in their lives, formulate

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hypotheses for possible solutions, generate new ideas, and discover outcomes based on those ideas (Abduloh et al., 2025). The creative process itself can be divided into two categories: inquiry-based creativity, which leads to discoveries, and recreation-based creativity, which leads innovations (Hidayat et al., 2018).

Critical thinking is a vital skill that must be developed to enable individuals to solve problems and draw conclusions from various possibilities (Syafitri et al., 2021). Critical thinking skills can be developed through learning activities conducted at school. During classroom learning, students are presented with a problem and required to find solutions or draw conclusions based on their analysis of the presented issue.

Learning outcomes are generally categorized into three domains: cognitive (knowledge), affective (attitudes), and psychomotor (skills). According to Simpson (1972) stated that the psychomotor domain is related to physical movement, coordination, and the mastery of motor skills. Assessment within the psychomotor domain is based on two level: concrete and abstract psychomotor performance. The concrete psychomotor level consists of: (1) imitation, (2) habituation, (3) proficiency, (4) naturalization, and (5) original action. Meanwhile, the abstract psychomotor level includes: (1) observing, (2) questioning, (3) experimenting, (4) reasoning, and (5) communicating. Furthermore, according to Leighbody (1968), the assessment of psychomotor learning outcomes includes: (1) students' ability to use tools and exhibit proper work attitudes, (2) their skill in analyzing and organizing a task, (3) the speed with which they complete assignments, (4) their ability to interpret symbols, and (5) the accuracy or conformity of their work to the expected standards.

Among the three variables discussed, critical thinking skills and learning outcomes are the most frequently assessed during the learning process. This trend is particularly evident at junior high school in Surakarta, where conventional teaching methods are still predominantly used. In such traditional classrooms, students typically listening to the teacher and taking notes, leaving limited opportunities to observe or assess students' creative abilities. In contrast, the present study aimed to comprehensively evaluate students' creativity, critical thinking skills, and psychomotor learning outcomes. These assessments were carried out through a project-based task, in which students were assigned to create a simple pop-up model.

This study was conducted to examine the effect of the Project-Based Learning (PjBL) model on students' creativity, critical thinking skills, and psychomotor learning outcomes in the IPA subject. The research was carried out among seventh-grade students from classes Science 1 and Science 2 at JUNIOR HIGH SCHOOL IN Surakarta, each consisting of 28 students. The core activity of the study involved a collaborative project in which students created a simple pop-up book based on the topic of *substances and their changes*. The project was conducted in groups, with each group consisting of 5 to 6 students. The assessment methods were adapted to suit each variable under investigation: critical thinking skills were evaluated through written tests, while creativity and psychomotor learning outcomes were assessed through non-test instruments

2. Method

This study was conducted at junior high school in Surakarta from September to November 2024 and focused on the topic of substances and their changes. The research employed a pretest-posttest control group design with random subject selection. This design involves the random selection of subjects and uses both pretests and posttests for assessment. Seventh-grade students served as the research sample. Data collection techniques included both test and non-test methods. Critical thinking skills were assessed using essay-based test items, while creativity and psychomotor learning outcomes were evaluated using non-test methods, such as questionnaires and observation sheets.

The instruments used in this study were tested for validity using the product-moment correlation validity test. The collected data were analyzed through prerequisite tests and hypothesis testing. The prerequisite tests included normality and homogeneity tests. After the data were confirmed to be normally distributed and homogeneous, hypothesis testing was conducted using the independent sample t-test. However, if the data were not normally distributed but remained homogeneous, the hypothesis testing was carried out using the Mann-Whitney test.

3. Results and Discussion

3.1. Research Data

3.1.1. Creativity Data

Creativity data were collected using a questionnaire consisting of 20 statements, including 12 positive and 8 negative items. Each indicator consisted of 3 positive and 2 negative items. Data collection through both the questionnaires and observations was based on aspects of creativity as proposed by Guildford (1986), namely fluency, flexibility, originality, and elaboration. In addition, each aspect in the creativity observation data consisted of three assessment indicators. Creativity questionnaire data can be seen in Table 1.

Table 1. Creativity Questionnaire Data

Class	Mean	Min	Max
Experiment	68.75	46	86
Control	70.96	46	84

Based on Table 1, the control class obtained a higher average creativity questionnaire score than the experimental class, with a mean score of 70.96. Next, creativity observation data can be seen in Table 2.

Table 2. Creativity Observation Data

Class	The Average of Creativity Aspects				The Overall Average
	Fluency	Flexibility	Originality	Elaboration	
Experiment	71.42	72.9	60.7	72.32	69.33
Control	92.25	91.21	45.12	87.01	78.92

Based on Table 2, it can be seen that the overall average creativity observation score of the control class is higher than that of the experimental class, with an average score of 78.92.

3.1.2. Critical Thinking Skill Data

Critical thinking data were collected using two instruments, a questionnaire and pretest-posttest essay questions (Table 3). The questionnaire consisted of 30 statements, including 14 positive and 16 negative statements. Meanwhile, the pretest-posttest consisted of 12 essay questions. Both instruments were developed based on six key critical thinking indicators (Facione, 2011), interpretation, analysis, evaluation, inference, explanation, and self-regulation.

Table 3. Critical Thinking Questionnaire and Pretest-Posttest Data

Class	Description	Mean	Min
Experiment	Questionnaire	63.36	43.3
	Pretest	31.05	19.4
	Posttest	62.8	38.9
Control	Questionnaire	77.75	54.7
	Pretest	43.34	25
	Posttest	74.8	47.2

Table 3 shows that the average scores of the control class are higher than those of the experimental class, with mean values 77.75 for the questionnaire, 43.34 for the pretest, and 74.8 for the posttest.

3.1.3. Psychomotor Learning Outcomes Data

Psychomotor learning outcomes were assessed using a questionnaire consisting of 18 statements, divided into 9 positive dan 9 negative items. Each indicator consisted of 3 positive and 3 negative items. Meanwhile, the observation instrument consisted of 3 assessment indicators for each aspect of psychomotor learning outcomes. The statements in both the questionnaire and observation data were based on the indicators of learning outcomes, namely experimenting, presenting results, and writing reports (Simpson, 1972). These indicators were adapted from Putra (2024), who stated that the assessment guidelines could be completed with flexible or open-ended responses. Psychomotor learning outcomes questionnaire data can be seen in Table 4.

Table 4. Psychomotor Learning Outcomes Questionnaire Data

Class	Mean	Min	Max
Experiment	64.29	35.6	88.9
Control	73.17	44.4	91.1

Table 4 shows that the average psychomotor learning outcomes questionnaire score of the control class was higher than that of the experimental class, with a mean score of 73.17. Next, based on Table 5, the overall average observation score of learning outcomes in the experimental class was higher than that of the control class, with a mean score of 78.49.

Table 5. Psychomotor Learning Outcomes Observation Data

Class	The Average of Learning Outcome Aspects			The Overall Average
	Experimenting	Presenting Results	Writing Report	
Experiment	86.03	58.95	90.5	78.49
Control	94.65	45.25	81.88	73.93

3.2. Hypothesis Testing Results

Hypothesis testing was performed using a t-test to determine the effect of the Project-Based Learning model on students' creativity, critical thinking skills, and learning outcomes. The results of this analysis are summarized in Table 6.

Table 6. Results of the T-test

Variable	Significance Value	Conclusion
Creativity Questionnaire	0.384	H0 is accepted
Critical Thinking Skill Questionnaire	0.000	H0 is rejected
Learning Outcome Questionnaire	0.007	H0 is rejected

Table 6 presents the results of the t-test, showing that the significance value for the creativity questionnaire was 0.384 > 0.05, for the critical thinking skills questionnaire was 0.000 < 0.05, and for the learning outcomes questionnaire was 0.007 < 0.05. Therefore, it can be concluded that the Project-Based Learning model did not have a significant effect on the creativity variable, but it had a significant effect on students' critical thinking skills and learning outcomes. Next, results of the Mann-Whitney test can be seen in Table 7.

Table 7. Results of The Mann-Whitney Test

Variable	Significant Value	Conclusion
Critical Thinking Skills Test	0,001	H_0 is rejected

Table 7 shows the results of the Mann–Whitney test for critical thinking skills, with a significance value of 0.001 < 0.05. Therefore, it can be concluded that the Project-Based Learning model has a significant effect on students' critical thinking skills.

3.3. Discussion

Based on the statistical tests performed independent samples t-test and the Mann–Whitney test, the following results were obtained. Using the independent samples t-test with a significance level of α = 0.05, creativity had a significance value of 0.384 > 0.05, and psychomotor learning outcomes had a significance value of 0.007 < 0.05. Meanwhile, the Mann–Whitney test for critical thinking skills produced a significance value of 0.001 < 0.05.

Assessment in this study was conducted not only through questionnaires and test instruments, but also through direct observation. Observation–based assessment was carried out throughout the learning process across six meetings, with the Project-Based Learning (PBL) model applied in the experimental class and the Discovery Learning model implemented in the control class. This assessment was guided by specific indicators related to creativity, critical thinking skills, and psychomotor learning outcomes.

3.3.1. Hypothesis on Students' Creativity

Creativity is the ability of students to generate new ideas, methods, or models for solving a problem (Astuti & Aziz, 2019). Many people assume that creativity refers to creating something entirely new. However, true creativity does not necessarily involve creating something that has never existed; rather, it often arises from the combination and reorganization of existing elements. According to Guilford (1986), students' creativity can be identified through four indicators: (1) fluency, (2) flexibility, (3) originality, and (4) elaboration (Sisk, 2021).

Regarding the fluency aspect, students in the experimental class were assessed based on the ideas they proposed (e.g., pop-up design, image selection, and image placement). In contrast, students in the control class were scored based on how they formulated hypotheses, expressed opinions, and asked questions during the practical activities. On the first day, none of the groups in the experimental class completed their projects; therefore, the work continued in the following session. On the second day, students began organizing the content and arranging the images to form their pop-up books. On the third day, students presented their pop-up projects which would be discussed in the learning outcome section. On the fourth day, a similar situation occurred as on the first day no group had yet completed their pop-up project. By the fifth day, students started completing and submitting their pop-up books. Meanwhile, in the control class, during the first to fifth meetings, students developed a hypothesis based on an image and then conducted a simple experiment. Throughout the activity, they also engaged in discussions related to the experiment. Based on observations over four days, the average score for the fluency aspect was 71.42 in the experimental class and 93.45 in the control class.

Figure 1. Project Result: Pop-Up Book from Group 1

Figure 2. Project Result: Pop-Up Book from Group 2

In the flexibility aspect, students in the experimental class were assessed based on how they solved problems, create pop-up effects, and corrected errors in their pop-up projects. Meanwhile, students in the control class were assessed based in how they solved problems, conducted experiments, and corrected mistakes during the experiment. When encountering difficulties, students in both classes would ask teacher or discuss the issue with their peers until they were able to solve it. However, some students in experimental class tended to simply follow along without making any meaningful contribution. Based on the observations for this aspect, the experimental class obtained an average score of 72.9, while the control class scored 91.05.

Figure 3. Project Result: Pop-Up Book from Group 3

Figure 4. Project Result: Pop-Up Book from Group 4

In the originality aspect, students in the experimental class were assessed based on how they created varied illustrations, developed unique pop-up models, and utilized varied materials. Meanwhile, students in the control class were evaluated based on their use of alternative tools and materials during experiments, their ability to generate new solutions when encountering problems, and their initiative to create something new from the available resources. During the pop-up creation process, students in the experimental class were given the freedom to use any materials and design their own pop-up models. However, several groups chose to use similar materials and designs, most commonly cardboard and HVS paper. Out of the five groups, two developed more distinctive pop-up models using alternative materials such as cotton and jute string. Despite some similarities, all groups produced different illustrations in their pop-up books. In contrast, students in the control class conducted experiments using predetermined tools and materials, although some students occasionally attempted to explore alternative materials. Based on observations of the originality aspect, the experimental class obtained an average score of 60.7 while control class achieved an average score of 45.12.

Figure 5. Project Result: Pop-Up Book from Group 5

In the elaboration aspect, students in the experimental class were assessed based on how they explained the materials, responded to questions, and presented the process of creating their pop-up books. Meanwhile, students in the control class were evaluated on their ability to explain the material, answer the questions on the worksheet, and describe the steps of the experiment. In the experimental class, students explained the topic of substances and their changes and demonstrated how to create the pop-up effect. During group discussions, they actively asked and answered question related to the material and the project, although some students remained passive. In the control class, students independently searched for relevant material while conducting the experiment, and then explained the content to their peers while completing the worksheet. Additionally, when some students encountered difficulties with the experimental procedure, their group members helped explain the steps in detail. Based on observations of the elaboration aspect over four days, the experimental class obtained an average score of 72.32, while the control class achieved an average score of 87.45.

3.3.2. Hypothesis on Students' Critical Thinking Skills

According to Facione (2011), critical thinking skills refer to the self-regulation involved in making decisions and generating interpretation, analysis, evaluation, inference, and explanation of a concept or consideration that serves as the basis for decision-making. The core of critical thinking consists of six key aspects: (1) interpretation, (2) analysis, (3) inference, (4) evaluation, (5) explanation, and (6) self-regulation. Utami et al. (2018) state that critical thinking skills can enhance the quality of thinking and enable individuals to consider alternative options beyond their initial capabilities. A supportive classroom environment is essential for fortering these skills by enabling students to explore multiple perspectives and engage in meaningful discussions.

In the learning process, critical thinking skills are essential for students. Those who are able to apply critical thinking tend to demonstrated a greater ability to understand and solve problems, as well as perform better on assessments. Therefore, it is important to cultivate these skills from an early age. Critical thinking encompasses the ability to analyze and evaluate information, understand arguments, and draw evidence-based conclusions (Ariadila et al., 2023).

The results of this study are consistent with findings by Suparmi et al. (2024), who implemented the Project-Based Learning (PjBL) model with Grade VIII students at SMP Negeri 30 Pekanbaru. Their study showed a significant effect of the PjBL model on students' critical thinking skills, with significance value of 0.027 < 0.05. Using the same model, research conducted by Astri also demonstrated an influence on critical thinking skills, which the average critical thinking scores of students taught using the PjBL model was higher than that of students taught using the conventional model.

The Project-Based Learning (PjBL) model is an instructional approach that encourages students to develop a project as a form of problem-solving. In this study, the PjBL model was implemented only in the experimental class, while the control class received instruction through a conventional learning model. At Junior high school in Surakarta, data were collected before and after the implementation of the PjBL model using a pre-test–post-test format. The test items were developed based on the indicators of critical thinking skills, which include interpretation, analysis, evaluation, inference, explanation, and self-regulation. Each indicator was represented by two open-ended essay questions comprehensively assess students' critical thinking abilities across all dimensions. Table 8 presents examples of student responses from the experimental and control classes in the interpretation aspect.

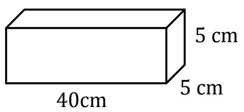
Table 8. Example of Students Responses in the Interpretation Aspect

Question	Everything that has mass and occupies space is called substance. Explain the properties and practice models of substance based on their states!	
Indicator	Score	
Able to identify the properties or characteristics of acids and bases Able to explain the particle model or the concept of acids and bases Able to distinguish the properties or characteristics of acids and bases	Score 1 = 1 indicator is demonstrated Score 2 = 2 indicators are demonstrated Score 3 = 3 indicators are demonstrated	
Example Answer		
Experiment Class	Control Class	Score
Solid, particle model: particles are tightly bound; properties: fixed shape and volume. Liquid, particle model: particles are bound but not too tightly; properties: fixed volume, flexible shape. Gas, particle model: particle is very loosely bound; properties: flexible shape and volume.	Solid, particle model: particles are strongly bound to each other, properties: fixed volume, fixed shape. Liquid, particle model: particles are bound to each other but not too strongly, properties: fixed volume, flexible shape. Gas, particle model: particles are very weakly bound, properties: flexible volume, flexible shape	3
Solid, properties: fixed shape and volume; particles: arranged regularly. Solid, properties: flexible shape, fixed volume; particles: weaker bonds than solids. Gas, properties: flexible shape and volume; particles: weak bond than solids.	Solid: its properties cannot change without specific conditions; its particles are dense and strong. Liquid: its properties change according to the container; its particles are loose and weak. Gas its properties fill the space, its particles are very loose and very weak.	2
Solid, particles are very dense. Liquid, particles are moderately dense. Gas, particles are very loosely packed	Solid: particles are close together. Liquid: particles are somewhat close together. Gas: particles are far apart.	1

Table 9 presents examples of student responses from the experimental and control classes in the analysis aspect.

Table 9. Example of Students Responses in the Analysis Aspect

Question: Observe the image below!



If the density of iron is 7,9 gr/cm3, determine the mass of the iron!

Indicator	Score	
Able to calculate mass or density Able to analyze the given image Able to break down formulas	Score 1 = 1 indicator is demonstrated Score 2 = 2 indicators are demonstrated Score 3 = 3 indicators are demonstrated	
Example Answer		
Experiment Class	Control Class	Score
$V = p \times l \times t$ $V = 40 \times 5 \times 5$ $7{,}9 = \frac{m}{1000}$	$V\ block$ $= 40 \times 5 \times 5$ Mass $= V \times density$ $= 1000 \times 7{,}9$	3

$V = 1000$ $\rho = \frac{m}{V}$	$m = 7{,}9 \times 1000$ $m = 7900\ gram$	= 1000 cm3 Density = 7,9 gr/cm3	$= 7900 gram$	
$\rho = \frac{m}{V}$ $7{,}9 = \frac{m}{1000}$	$m = 7{,}9 \times 1000$ $m = 7900\ gram$	$m = 7{,}9 \times 1000$ $m = 7900\ gram$		2
$\rho = \frac{m}{V}$ $7{,}9 = \frac{1000}{V}$	$V = \frac{1000}{7{,}9}$ $V = 126\ gram$	$V = p \times l \times t$ $V = 40 \times 5 \times 5$ $V = 1000$ $\rho = \frac{m}{V}$	$7{,}9 = \frac{1000}{V}$ $V = \frac{1000}{7{,}9}$ V = 126 gram	1

Table 10 presents examples of student responses from the experimental and control classes in the evaluation aspect.

Table 10. Example of Students Responses in the Evaluation Aspect

Question	A person wants to separate red blood cells and white blood cells from blood plasma. The person uses a separation method. What do you think about the method used?
Indicator	**Score**
• Able to explain the method / process that occurred • Able to express an opinion based on a statement • Able to identify the method / name of the process	• Score 1 = 1 indicator is demonstrated • Score 2 = 2 indicators are demonstrated • Score 3 = 3 indicators are demonstrated

Example Answer		
Experiment Class	Control Class	Score
Incorrect, it should be done using the centrifugation method, which utilizes centrifugal force (a outward force that separates substances from their components by spinning them rapidly)	That method is incorrect, because the separation of erythrocytes and leukocytes in blood plasma must use the centrifugation method	3
Incorrect, because the correct method is centrifugation	It is better to use the centrifugation method	2
Less appropriate, it should use another method	It is inaccurate, because the filtration method is used to separate coffee from its grounds	1

Table 11 presents examples of student responses from the experimental and control classes in the inference aspect.

Table 11. Example of Students Responses in the Inference Aspect

Solution	pH	Solution	pH
A	5.2	F	7.0
B	9	G	2
C	7.9	H	12
D	8.1	I	8.2
E	6.6	J	3.6

Nina was testing several solutions using pH indicator paper. The test results were then recorded in a prepared data table. Groups the solutions and provide justification!

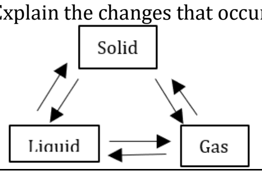
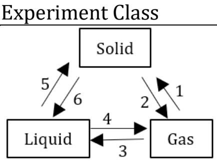
Indicator	Score
Able to classify solutions or objects	Score 1 = 1 indicator is demonstrated
Able to mention the name of the classification	Score 2 = 2 indicators are demonstrated
Able to provide a reason for the classification	Score 3 = 3 indicators are demonstrated

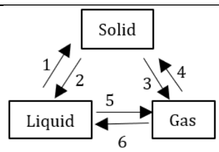
Example Answer		
Experiment Class	Control Class	Score
Acidic: A, E, G, and J – because they have a pH value less than 7 Neutral: F – because its pH value is equal to 7 Basic: B, C, D, H, and I – because they have a pH value greater than 7	Acidic: A, E, G, J – because pH < 7 Basic: B, C, D, H, I – because pH > 7 Neutral: F – because pH = 7	3
pH < 7: A, E, G, J pH 7: C, F pH > 7: B, D, H, I	Acidic: A, E, G, J – because pH > 7	2

Reason: To identify the differences between acids and bases.	Basic: B, C, D, H, I – because pH < 7 Neutral: F – because pH = 7	
Acidic: B, C, D, H, and I Basic: A, E, G, and J Salt: F	Acidic: B, C, D, H, I – because pH > 7 Basic: A, E, G, J - because	1

Table 12 presents examples of student responses from the experimental and control classes in the explanation aspect.

Table 12. Example of Students Responses in the Explanation Aspect

<table>
<tr><td colspan="5">Explain the changes that occur

</td></tr>
<tr><td colspan="2">Indicator</td><td colspan="3">Score</td></tr>
<tr><td colspan="2">Able to analyze the given image
Able to explain the changes that occurred
Able to mention the changes or provide examples</td><td colspan="3">Score 1 = 1 indicator is demonstrated
Score 2 = 2 indicators are demonstrated
Score 3 = 3 indicators are demonstrated</td></tr>
<tr><td colspan="5">Example Answer</td></tr>
<tr><td colspan="2">Experiment Class</td><td colspan="2">Control Class</td><td>Score</td></tr>
<tr><td>

1 = Crystallization: The change of state from gas to solid. Example: the formation of salt crystals.
2 = Sublimation: The change of state from solid to gas. Example: camphor sublimating.</td><td>3 = Condensation: The change of state from gas to liquid. Example: morning dew formation.
4 = Evaporation: The change of state from liquid to gas. Example: boiling water.
5 = Freezing: The change of state from liquid to solid. Example: the formation of ice cubes.
6 = Melting: The change of state from solid to liquid. Example: melting ice.</td><td>

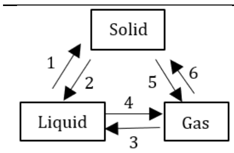
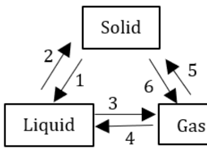
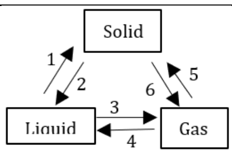
1 = Freezing: liquid becomes solid
2 = Melting: solid becomes liquid
3 = Sublimation: solid becomes gas
4 = Crystallization: gas becomes solid</td><td>5 = Condensation: gas becomes liquid
6 = Evaporation: liquid becomes gas</td><td>3</td></tr>
<tr><td>
</td><td>1 : Freezing
2 : Melting
3 : Condensation
4 : Evaporation
5 : Sublimation
6 : Crystallization</td><td>
</td><td>1: Melting
2: Freezing
3: Evaporation
4: Condensation
5: Crystallization
6: Sublimation</td><td>2</td></tr>
<tr><td colspan="2">Freezing: liquid to solid
Melting: solid to liquid
Sublimation: solid to gas
Crystallization: gas to solid
Condensation: gas to liquid
Evaporation: liquid to gas</td><td>
</td><td>1: Melting
2: Freezing
3: Evaporation
4: Condensation
5: Sublimation
6: Crystallization</td><td>1</td></tr>
</table>

Table 13 presents examples of student responses from the experimental and control classes in the self-regulation aspect.

Table 13. Example of Students Responses in the Self-Regulation Aspect

Question	You and your friend Evan are playing in the river. While playing in the water, Evan feels something touch his foot. It turns out to be a plastic water bottle. You and Evan look toward where the bottle came from and see that the river surface is covered with many discarded bottles. What would you do?
Indicator	Score
• Able to determine the action taken • Able to show the activity carried out • Able to apply the action taken	• Score 1 = 1 indicator is demonstrated • Score 2 = 2 indicators are demonstrated • Score 3 = 3 indicators are demonstrated

Example Answer		
Experiment Class	Control Class	Score
Write a sign along the riverbank that says "Dispose of trash properly", provide trash bins by the river, and encourage the community to help clean the river	I will collect and dispose of mineral water bottles, then prepare trash bins located around the river	3
Clean up the bottles and throw them into the trash bin, as well as put up a warning sign not to litter in the river.	Cleaning up trash, protecting the river environment	2
Pick up the plastic bottle and throw it into the trash bin.	Cleaning the river	1
Pick up the plastic bottle and throw it into the trash bin.	Cleaning the river	1

3.3.3. Hypothesis on Students' Learning Outcomes

Learning outcomes refer to students' achievements as measured through assessments such as exams, assignment, participation, questioning, answering, and other factors that contribute to their academic performance (Dakhi, 2020). Learning outcomes are generally categorized into three domains: Cognitive (knowledge), affective (attitude), and psychomotor (skills). The psychomotor domain relates to motor skills, object manipulation, coordination, and observation (Andriani & Rasto, 2019). According to Sudjana (2013), psychomotor learning outcomes represent the skills and abilities possessed by each individual, enabling students to gain new learning experiences through performance-based activities. Putra (2024) states that the assessment of psychomotor learning outcomes can be conducted through observation, which is frequently used to measure both individual behavior and process-based learning performance. Therefore, observation-based assessments can be understood as a means of evaluating both the learning process and its outcomes. The assessment of psychomotor learning outcomes is based on levels of abstract psychomotor development, which include: (1) observing, (2) questioning, (3) experimenting, (4) reasoning, and (5) communicating.

In the experimenting aspect, students in the experimental class were assessed based on their preparedness of tools and materials, the process of creating the pop-up project, and their effort in finding relevant project materials. During the activity, one group forgot to bring their materials, which prevented them from continuing the project, but they compensated by researching pop-up models using through the internet. Additionally, students independently searched for the learning material, wrote it down, and attached it to their pop-up projects. Meanwhile, students in the control class were evaluated based on their preparedness of tools and materials, their accuracy during the practical activity, and their effort in finding information to answer the worksheet. During the practical sessions, some groups did not bring the required materials, prompting them to borrow from other groups. In some cases, the groups divided tasks two students conducted the experiment while three completed the worksheet. However, most groups conducted the experiment together before completing the worksheet. Over four days of observation, the average score for the experimenting aspect was 86.03 for the experimental class and 94.65 for the control class.

In the presenting results aspect, students in both the experimental and control classes were assessed based on their use of clear and comprehensible language, attentiveness to other groups' presentations, and their ability to respond to questions from peers. After completing their projects, students in the experimental class presented their pop-up project outcomes in groups. Similarly, students in the control class conducted presentations after completing their worksheet. The presentations of the pop-up project for the experimental class and the practical work for the control class were conducted two days after the completion of each respective activity. Based on observations over two days, the average score for the presenting results aspect was 58.95 for the experimental class and 45.25 for the control class.

In the report writing aspect, students were provided with worksheets to record their project reports or learning activities. Students in the experimental class were assessed based on their ability to distribute tasks among group members, develop an activity schedule, and design a project plan.

During the project work, students filled out the worksheets, which included sections for task distribution, activity scheduling, and project design. At the beginning of the sessions, many students found it difficult to create an activity schedule and project design. However, they actively asked questions to the teacher and discussed with their peers to complete these components. Based on four days of observation, the average score for the report writing aspect was 90.5 for the experimental class and 81.88 for the control class.

4. Conclusion

Based on the data analysis and discussion, the following conclusions can be drawn: (1) The Project-Based Learning (PjBL) model does not have a significant effect on students' creativity, as indicated by the independent t-test result showing a significance value of 0.384 > 0.05. This finding is supported by the lower average observation score of the experimental class (69.33) compared to the control class (78.92). (2) The Project-Based Learning (PjBL) model has a significant effect on students' critical thinking skills, as shown by the independent t-test result for the questionnaire instrument (0.000 < 0.05) and the Mann-Whitney test result for the pretest-posttest scores (0.001 < 0.05). (3) The Project-Based Learning (PjBL) model has a significant effect on psychomotor learning outcomes, with a significance value of 0.007 < 0.05. This finding is further supported by the higher average observation score of the experimental class (78.49) compared to the control class (73.93).

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