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Enhancing Students' Creativity through Product-Oriented Project-Based Learning with Teaching Aids in Straight Motion Kinematics

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Abstract: This study aims to analyze the implementation of product-oriented project-based learning using instructional teaching aids to improve students' creativity in learning the topic of straight motion kinematics. The aspects of creativity examined include fluency, flexibility, elaboration, and evaluation skills. This research employed an experimental method with a nonequivalent control group design. The research subjects consisted of an experimental class that applied product-oriented project-based learning using teaching aids and a control class that received conventional instruction. Data were collected through creativity tests and observation sheets. The results of the study indicate that the implementation of product-oriented project-based learning using teaching aids effectively improves students' creativity. This improvement is demonstrated by the achievement of the creativity indicators, including fluency, flexibility, elaboration, and evaluation skills, in the experimental class compared to the control class. Therefore, product-oriented project-based learning using teaching aids can be considered an effective alternative instructional strategy to enhance students' creativity in physics learning.

Keywords: Creativity; Project Based Learning; Teaching Aids

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Introduction

Creativity is one of the essential competencies in 21st-century education, as it enables students to generate ideas, solve problems, and develop innovative solutions needed in various learning contexts. Creativity is considered a core skill necessary for achieving successful learning outcomes in science education, including physics, because it supports students in thinking divergently and constructing knowledge independently (Sari & Hidayat, 2019; Fahlevi et al 2022). Research in physics education has demonstrated that learning models which allow active student engagement contribute significantly to the development of students' creative thinking abilities (Efendi et al., 2021).

Despite its importance, physics learning in many classrooms is still predominantly teacher-centered, which often limits students' opportunities to explore and express their ideas. This limitation can hinder the development of key creative thinking skills, such as fluency, flexibility, elaboration, and evaluation (Rahmawati & Putra, 2020). Physics content is often abstract and conceptual; therefore, traditional lecture-based instruction may reduce students' active involvement and impede the development of higher-order thinking skills, including creativity (Sari & Hidayat, 2019).

One of the widely recommended instructional models to overcome these limitations is Project-Based Learning (PjBL). PjBL engages students in meaningful, real-world tasks that require them to investigate problems, collaborate with peers, and produce tangible products as learning outcomes. Quasi-experimental studies have shown that the implementation of PjBL can significantly enhance students' creative thinking abilities in physics compared to conventional instructional methods (Nugroho & Wibowo, 2022).

In addition to quasi-experimental research, other studies in science education have found that the use of PjBL can improve students' creative thinking and creative performance, particularly in terms of fluency, flexibility, and idea elaboration (Lestari & Santika, 2023). Systematic reviews of the literature further indicate

that PjBL is effective in fostering creativity across various science learning contexts (Sari & Hidayat, 2019; Pangat et al, 2020).

Integrating instructional teaching aids as products of PjBL represents a relevant strategy in physics learning because such tools help students visualize abstract concepts and make learning more concrete and meaningful. The process of designing and producing teaching aids allows students to express their creative ideas and engage in deeper cognitive activities while evaluating their products (Lestari & Santika, 2023).

Although previous research has examined the effectiveness of PjBL in enhancing creativity, studies that specifically investigate product-oriented PjBL using teaching aids in straight motion kinematics—particularly among 11th-grade high school students—remain limited in the literature. Straight motion kinematics is a fundamental concept in physics that often requires visualization and modeling to support student understanding. Therefore, implementing product-oriented PjBL with teaching aids is expected to increase student engagement in the learning process while enhancing their creativity in understanding and applying the principles of straight motion kinematics.

Methods

This study employed an experimental method with a quasi-experimental design using a Nonequivalent Control Group Design. The independent variable was the implementation of teaching-aid–oriented Project-Based Learning (PjBL), while the dependent variable was students' creativity, operationally defined through indicators of fluency, flexibility, elaboration, and evaluation.

The population consisted of 11th-grade students at State Senior High School 1 Semarang. Using a purposive sampling technique, four classes were selected as the study sample, totaling 140 students, with two classes assigned as the experimental group and two as the control group. Group assignment was based on existing class structures, and pretest scores were used to ensure equivalence between groups prior to the intervention.

Procedures for the experimental group involved the implementation of teaching-aid–oriented PjBL, where students designed and utilized teaching aids to understand straight motion kinematics. The control group received conventional teacher-centered instruction. Both groups completed pretests and posttests to measure students' creativity.

Instruments included a creativity skills test consisting of 10 essay questions, which had been validated and tested for reliability, yielding a reliability coefficient of 0.85. The test was designed to assess students' creative thinking skills based on the indicators of fluency, flexibility, elaboration, and evaluation. Data analysis was conducted as follows: Paired-samples t-tests were used to assess within-group improvements in creativity, while independent-samples t-tests compared creativity between the experimental and control groups. Normality and homogeneity assumptions were tested prior to conducting the t-tests. Effect size (Cohen's d) was calculated to evaluate the magnitude of the differences. Normalized gain (n-gain) was computed to measure the relative improvement in students' creativity scores, following Hake (2002).

Results and Discussion

The results of this study on the creativity of 11th-grade students at State Senior High School 1 Semarang, using the project-based learning model, in the kinematics of linear motion, are as follows:

Analysis of the Influence of the Implementation of the Project Based Learning Model Oriented to Teaching Aids on Increasing Students' Learning Creativity

Learning tools are used to optimize classroom learning. These tools include teaching modules, questionnaires, and linear motion kinematics problems. These tools are assessed by several validators.

The results of the analysis indicate that the above instruments are suitable for use as a support for this research. The PjBL learning module was analyzed by three validators with an average score of 3.96, a good criterion for use in class as a teacher's teaching guide. The PBL learning module was analyzed by three validators with an average score of 3.93, a good criterion for use in class as a teacher's teaching guide. The

linear motion kinematics questions were analyzed with a score of 3.9, a very good criterion. The independence questionnaire was analyzed with a score of 3.83, a good criterion.

Table 1. Instrument Analysis

Instrument	Validator 1	Validator 2	Validator 3	Average	Criteria
PjBL teaching module	3.9	4.0	4.0	3.96	Good
PBL teaching module	3.8	4.0	4.0	3.93	Good
Physics questions	3.8	4.0	3.9	3.90	Good
Questionnaire	3.9	3.8	3.8	3.83	Good

The validity test in this study was carried out using the Statistical Package Social Science (SPSS) 21.00 program with the test criteria that if the correlated item-total correlation is greater than 0.5, then the data is a strong construct (valid).

Table 2. Validity Analysis Results

No	Criteria	Question number	Number of questions
1	Valid	1,2,3,4,5,6,7,8,9,10,11,12	12
2	Non-Valid	-	-

Analysis of 12 valid questions. Valid questions meet the research criteria; each valid question item, based on the analysis results, is categorized as valid and can be used.

Item Reliability

The reliability test of this research used the Statistical Package Social Science (SPSS) 21.00 program. The results of the question analysis r_{11} is greater than r_{tabel} N = 12 and the significance is 0.576 is 0.913 > 0.576 which means that the question instrument is reliable, so it can be used as a reliable data collection tool.

Table 3. Reliable Analysis for Static Fluid Problems

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.913	0.915	12

Data Normality

The normality test was carried out using SPSS Statistics 21.00 with the Colmograph-Smirnov test. The hypotheses to be tested are as follows:

H_0: Data comes from a normally distributed sample
H_1: Data comes from a non-normally distributed sample

The hypothesis testing criteria are H_0 is accepted if the significance value is ≥ 5%. The output results are presented in the following table.

Table 4. Data Normality Test

Tests of Normality							
Group		Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	Df	Sig.	Statistic	Df	Sig.
Creativity	Experiment	.092	70	.200	.973	70	.137
	Control	.082	70	.200	.971	70	.102

Based on the Kolmogorov-Smirnov test on the output above with a significance level of 5%, the experimental class's significance is 0.137 > 0.05, so H_0 is accepted, and the control class's significance is 0.102 > 0.05, so H_0 is accepted. This means that the research sample is normally distributed.

Homogeneity test

The homogeneity test in this study was conducted using SPSS Statistics 21.00 using the Leneve Statistical test with a 5% significance level. The criteria for acceptance of H_0 is if the significance value is > 5%. The output results are presented in the table below.

Table 5. Homogeneity test output

Creativity	Test of Homogeneity of Variances	
	Levene Statistic	Sig.
Mean	.145	.704

Based on the SPSS output results above, the significance value of homogeneity is 0.704 > 5%, so based on the testing criteria, H_0 is accepted. This means there is no significant difference in variance between the experimental class and the control class.

T-Test and N-Gain Test

The Independent T-test analysis in this study was used to analyze the increase in student creativity between the experimental and control classes. The results of the Independent T-test using SPSS Statistics 26 can be seen in the following table.

Table 6. T-test Results

Class		N	Mean	Std. Deviation	T	Sig.
Creativity	Experiment	70	49.84	7.634	4.322	0.329
	Control	70	44.44	7.140	3.242	0.129

Based on the T-test results above, the significance value is 0.329. According to the decision-making criteria, a significance value of 0.329 > 0.05 means H_0 is rejected and H_a is accepted. This indicates that the Project-Based Learning model has an effect on student creativity.

To calculate the magnitude of the increase in pretest-posttest results for linear motion kinematics material, the N-gain test was used statistically. The results of the N-gain test for student creativity data are explained as follows.

Table 7. N-gain Test Results

Class	N	N-gain	Criteria
Experiment	70	0.74	High
Control	70	0.6	Medium

Based on the results of the N-Gain Test output above, the number of students in the experimental class was 70 and the control class was 70, so the total number of students in this study was 140. The experimental class obtained a mean score of 0.74, while the control class obtained a mean score of 0.6. This study shows that the Project Based Learning model has an effect on student learning creativity. The results of the increase in student creativity in the experimental and control classes are shown in the following graph.

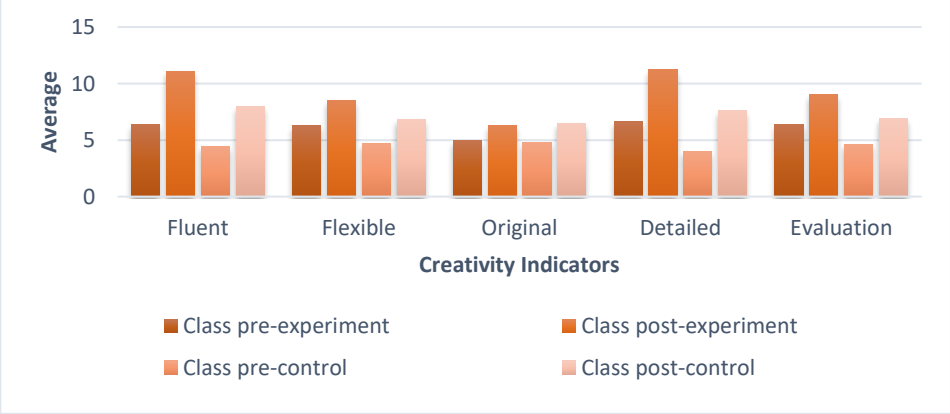

Figure 1. Creativity Results in The Experimental Class and Control Class

Figure 1 illustrates the average scores of creativity indicators among students in both the experimental and control classes before and after the intervention. The creativity indicators measured include fluency, flexibility, originality, detail, and evaluation. However, no research has examined how the ability to produce original thinking is related to real-life achievements (Perry & Karpova, 2017; Massyrova et al, 2015; Farihatun et al, 12019). Therefore, studies on creativity and real-life achievements are worth considering.

It is evident that the experimental class showed an increase in average scores across all creativity indicators following the intervention (post-experiment) compared to the pre-intervention scores (pre-experiment). The most significant improvements were observed in the fluency and detail indicators, suggesting that the implementation of teaching-aid–oriented Project-Based Learning effectively enhanced students' ability to generate ideas fluently and develop them with greater detail. However, it is important to note that this review has a significant limitation, namely the lack of clear differentiation between Project-Based Learning and Problem-Based Learning, as highlighted by (Guo et al, 2020; Sine 2021). In comparison, (Safriana et al, 2022; Safaruddin et al, 2020) reported that the STEAM-based Project-Based Learning model positively impacts students' creative thinking skills on the concept of optical instruments. This finding is supported by a hypothesis test result showing a significance value of 0.017 (2-tailed), which is below the 0.05 significance level. Furthermore, questionnaire data indicate that students who participated in STEAM-based Project-Based Learning had a response rate of 71.67%, higher than the 66% response rate of students who did not use this learning model.

In contrast, the control class showed relatively smaller increases in average creativity scores between the pre-control and post-control phases. This indicates that the conventional teaching methods applied in the control class were less effective in fostering students' creativity compared to the intervention used in the experimental class. Overall, these data reinforce the finding that the teaching-aid–oriented Project-Based Learning approach has a more substantial positive impact on students' creativity development than conventional instruction.

Conclusion

Based on the results of the analysis, the implementation of teaching-aid–oriented Project-Based Learning (PjBL) demonstrated an improvement in students' creativity compared to the control group. The results of the independent-samples t-test indicated a statistically significant difference between the experimental and control groups ($p < 0.05$), and the N-gain analysis showed that the experimental group achieved a higher relative improvement in creativity.

This study has some limitations, including the use of a sample from a single school, which may limit the generalizability of the findings. In addition, the creativity assessment instrument was limited to specific indicators and could be further developed in future research. Overall, the findings suggest that the implementation of teaching-aid–oriented PjBL can be an effective strategy for enhancing students' creativity in learning straight motion kinematics, with the interpretation of results considered in light of the study's limitations.

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