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The Effectiveness of the Project-Based Learning Model to Enhance High School Students' Problem-Solving Skills in the City of Mataram, West Nusa Tenggara

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Abstract

21st-century physics learning requires problem-solving skills, but school practices often remain teacher-centred and formula-oriented. This study aims to analyze the effect of implementing a project-based learning model on 11th-grade students' problem-solving skills in linear motion at SMA Negeri 2 Mataram. The research used a one-group pretest-posttest design with a purposively selected sample of 71 students. The results indicated strong validity (17 of 20 items were valid) and high reliability (KR-20 = 0.854). The average score went up from 63.24 on the pretest to 70.12 on the posttest. Normality testing confirmed that the data were normally distributed, and the paired sample t-test showed a significant difference (t-value of 5.527 exceeded the t-table value of 2.000). These findings confirm that project-based learning is efficacious in improving students' problem-solving skills. The PjBL model is effective in developing these skills and can serve as an innovative learning strategy to enhance physics learning in secondary schools.

Keywords: Project-Based Learning, 21st Century Learning Model, Learning Innovation, Problem-Solving Skills, Student Centred Learning.

INTRODUCTION

Project-Based Learning (PjBL) is an educational approach that is highly relevant in the 21st century because it emphasizes students' active engagement in solving real-world problems and producing authentic products (AlAli, 2024; Sah et al., 2024). Critical thinking, collaboration, communication, and creativity are among the key skills that can be integrated into this model. These skills are essential for meaningful learning (Kurniahtunnisa et al., 2023; Williamson, 2023). PjBL does not focus solely on outcomes; it also emphasizes the learning process, including conducting in-depth investigations and reflecting on learned concepts (Kokotsaki et al., 2016; Wulandari et al., 2025).

The PjBL model enhances students' problem-solving abilities (Jalinus et al., 2019). In formulating problems, testing hypotheses, and evaluating generated solutions, students are challenged to think analytically (Loyens et al., 2023; Situmorang et al., 2022; Zulyusri et al., 2023). Moreover, this model transforms the role of teachers from being the primary source of information to facilitators who encourage exploration and learner autonomy. Project-based and collaborative processes improve students' ability to connect theory with real-world situations. As a result, the concepts learned become more contextual and are retained more effectively in memory (Omelianenko & Artyukhova, 2024). In addition, project-based learning can foster modern skills through problem-solving tasks and teamwork, indicating that PjBL is a practical instructional approach (Hidayatullah et al., 2025).

Previous studies have shown that PjBL can enhance higher-order thinking skills, including problem-solving. Rasyidi (2024) found that PjBL helps students generate innovative solutions to scientific problems. Similar results were reported by Syafila and A'yun (2024), who found that students taught using PjBL improved their ability to analyze and evaluate physical concepts. Furthermore, research by Nadawina et al. (2025) demonstrated that PjBL can be effectively applied to kinematics topics.

However, in general, students' problem-solving skills in Indonesia remain low, as indicated by PISA results, which place Indonesian students in a weak category in terms of reasoning and concept application. This phenomenon suggests that classroom learning is still dominated by conventional, teacher-centered methods that emphasize rote memorization of formulas. Similar issues were identified at SMA Negeri 2 Mataram, where preliminary observations and interviews with physics teachers revealed that eleventh-grade students tend to be passive and struggle with non-routine problems involving linear motion. Students are more accustomed to solving procedural problems that closely resemble the teacher's examples, resulting in underdeveloped analytical and

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conceptual application skills. This condition is consistent with the findings of Hidayatullah and Widhyastuti (2025), who stated that science instruction that emphasizes routine procedures and is dominated by the teacher's role hinders the development of students' analytical and problem-solving abilities.

Considering these conditions, this study aims to evaluate the effect of the project-based learning model on the problem-solving skills of eleventh-grade students at SMA Negeri 2 Mataram in the topic of linear motion. The novelty of this research lies in examining the effectiveness of PjBL within a local context at an urban flagship senior high school. This study employs a pre-experimental design using a comprehensive essay test instrument. The findings are expected to contribute theoretically to the development of constructivist-based learning models and to provide practical implications for teachers and policymakers in improving the quality of physics instruction at the secondary school level.

MATERIALS AND METHODS

Time and Place

This research was conducted from July to August 2025 at SMA N 2 Mataram. This school is located in Mataram City, West Nusa Tenggara, Indonesia. This research examined linear motion among 11th-grade students.

Research Design

This study used a pre-experimental method with a one-group pretest-posttest Design. The experimental group was given treatment by applying a project-based learning (PjBL) model. Tests were conducted before and after treatment to determine changes in student learning outcomes. The following is the research design (Sugiyono, 2019).

Group	Pretest	Treatment	Posttest
Exsperiment	O_1	X	O_2

Description:

- O_1 = Pretest to determine the initial abilities of students
- X = Treatment in the form of implementing the Project-Based Learning model
- O_2 = Final test (posttest) to determine the improvement in learning outcomes after treatment

This design is used to determine the effectiveness of the problem-based learning model in improving student learning outcomes in vector, GLB, and GLBB materials.

Population and Sample

This study involved all 11th-grade science students at SMA Negeri 2 Mataram in the 2025–2026 academic year. This study used purposive sampling, meaning the sample was selected based on specific criteria: classes with balanced characteristics and that received the same materials. Students from science classes 7 and 8 were selected as the sample for this study. The project-based learning model was used for both.

Research Instrument

This study used physics achievement tests to measure students' mastery of concepts and their abilities in vectors, GLB, and GLBB, both before and after using the project-based learning model. The learning outcome test consists of twenty multiple-choice questions with five answer choices (A–E). For each correct answer, one point is given, and for each incorrect answer, zero points are given. The total score is then converted to a 0 to 100 scale.

Table 1. Research Instrument Indicators

Measured Indicators	Question Number	Cognitive Domain (Bloom)
Determining the magnitude and direction of the resultant of two or more force/displacement vectors.	1, 2, 3, 5, 6	C2 – C3
Determining the relationship between vectors in diagrams and the direction of displacement.	4, 7, 8, 9	C2 – C4
Analyzing the application of vectors in motion (travel, trajectory, direction of displacement)	10	C4
Determining the time, distance, or position of an object based on a constant speed.	11, 12	C2 – C3
Determining acceleration, final velocity, or time based on changing motion data.	13, 14, 15	C2 – C3
Interpreting speed-time graphs to determine speed or distance.	16	C4
Determining the distance or speed of an object undergoing constant acceleration.	17, 18	C2 – C3
Analyzing the vertical upward motion and free fall of an object (with g = 9.8 m/s²).	19, 20	C3 – C4

Experts assess content validity to ensure that the questions are appropriate for the indicators and basic competencies. Reliability is tested using the Kuder–Richardson 20 (KR-20) or KR-21 formula, with the following interpretation: $r_{11} \geq 0.70 \rightarrow$ reliable and $r_{11} < 0.70 \rightarrow$ needs revision. Each correct answer is given a score of 1, and each incorrect answer is given a score of 0. The final score is calculated using the formula: $\text{Score} = \frac{\text{Score Obtained}}{\text{Maximum Score}} \times 100$. These scores are then used to analyze learning improvement by comparing pretest and posttest scores.

Research Procedure

This research procedure was carried out in three main stages, namely the preparation stage, the implementation stage, and the final stage. In the preparation stage, the researcher identified the research sample classes, namely XI Science 7 and XI Science 8, and then developed project-based learning tools, including lesson plans, student worksheets, and test instruments. All learning tools and instruments were validated before use, and a pretest was conducted to assess students' initial abilities. In the implementation stage, the project-based learning (PjBL) model was applied in several meetings on the topics of vectors, GLB, and GLBB. The teacher served as a facilitator and mentor during the project activities, while the students worked in groups to complete physics-related projects. In the final stage, the researcher conducted a posttest to measure learning outcomes after the implementation of PjBL, then collected, processed, and analyzed the pretest and posttest data. Based on this analysis, conclusions were drawn regarding the effectiveness of the project-based learning model in improving student learning outcomes.

Research data analysis

The data obtained was analyzed using the following steps:

Normality Test

To determine whether the pretest and posttest data have a normal distribution. The Shapiro-Wilk test at the 0.05 significance level can be used to perform this check.

Hypothesis Testing (Paired Sample t-Test)

To determine whether there is a significant difference between the pretest and posttest results, a t-test is used—testing method: A two-tailed Sig. A value below 0.05 indicates a statistically significant difference, indicating that the Project-Based Learning model helps students solve problems better—conversely, a two-tailed Sig. A value greater than 0.05 indicates no significant difference.

RESULTS AND DISCUSSION

Result

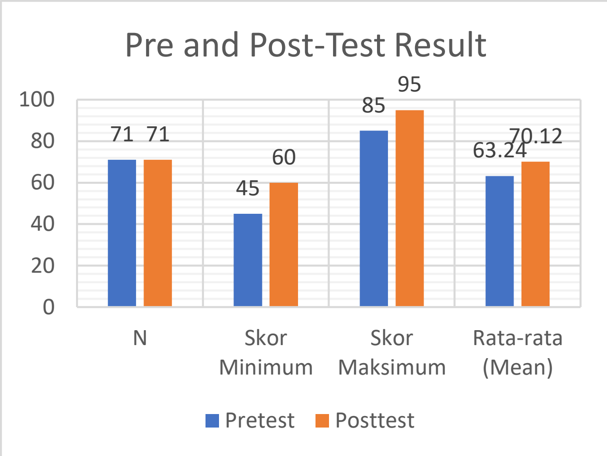
Results of Instrument Validity and Reliability Testing

Based on the results of the validity test conducted on 20 test items with 71 respondents (df = 69, r-table = 0.233 at a 5% significance level), 17 items were valid, and 3 were invalid. An item is considered valid if the calculated correlation coefficient (r-calculated) is greater than the r-table value. The results indicate that most items had r-calculated values ranging from 0.241 to 0.726, which exceed the r-table value (0.233) and are therefore deemed valid. In contrast, item number 2 (r-calculated = 0.198), item number 13 (r-calculated = 0.212), and item number 18 (r-calculated = 0.175) showed correlation coefficients lower than the r-table value and were thus classified as invalid. Consequently, 17 of the 20 items were considered suitable for use in subsequent stages of the research. These findings indicate that, overall, the instrument demonstrates good validity, as most of its items consistently measure the intended construct.

The reliability test results for the 20 test items indicate that the instrument's reliability coefficient was 0.854. This value was obtained using the Kuder–Richardson Formula 20 (KR-20) calculated with the assistance of SPSS software, ensuring that the results are accurate and trustworthy. According to Guilford's (1956) reliability interpretation criteria, a reliability coefficient above 0.70 reflects a very high level of consistency. Therefore, the coefficient of 0.854 indicates excellent reliability, meaning the test items exhibit strong internal consistency in measuring the construct of problem-solving skills. Overall, the instrument used in this study is reliable and appropriate for data collection, as it produces stable, consistent measurement results.

Pretest and Posttest Results

To clarify the comparison of student learning outcomes before and after the treatment, Figure 1 shows the difference between the pretest and posttest scores in the experimental group. This figure shows the change in the average score obtained by 71 students.



Graph 1. Results of Pre- and Post-tests on Students' Problem-Solving Skills

Based on Figure 1, there is an increase in the mean score from a pretest value of 63.24 to a posttest value of 70.12. This indicates that, after the instructional intervention was implemented, students' learning outcomes improved substantially. This increase reinforces the results of the previous descriptive analysis, suggesting that the learning model applied to the experimental group improved students' learning outcomes. Visually, the graph shows a clear distinction between the conditions before and after the intervention, with scores trending upward.

Data Normality Test Results

A normality test was conducted to determine whether the data were normally distributed. The significance level for the normality test was 0.05, and it was conducted using the Kolmogorov-Smirnov test in SPSS. The results of the normality test of the data in the Kolmogorov-Smirnov column are presented in Table 2 below.

Table 2. Data Normality Test

Data	Pretest	Posttest
N	71	71
Sig. (p-value)	0.200	0.187
Shapiro-Wilk Statistic	0.089	0.094
Description	Normal	Normal

Results of Hypothesis Testing of Students' Problem-Solving Skills

To determine whether there was a difference in students' problem-solving skills before and after being taught using the Project-Based Learning model, a Paired Sample t-Test was conducted. This test was conducted using the SPSS program at a significance level (α) of 0.05. The number of samples analyzed was 71 students, resulting in a degree of freedom (df) of 70. The results of the t-test are presented in the following table.

Table 4. T-test for Problem-Solving Skills

Description	Result
Paired of Data	Pretest – Posttest
N	71
Mean	70.12
t value	-5.527
Df	70
t table	2.000
Sig. ($\alpha = 0.05$)	0.05
Description	**Significant**

Based on the results of the Paired Sample t-Test in Table 4 above, the calculated t-value is -5.527, while the table t-value is 2.000 at a significance level of 0.05 with df = 70. Because the value |t-calculated| > t-table (5.527 > 2.000), H_0 is rejected and H_1 is accepted. This indicates a significant difference between the pretest and posttest results, suggesting that the Project-Based Learning model improves students' problem-solving skills.

Discussion

Project-Based Learning (PjBL) is a learning approach that emphasizes students' active involvement in the learning process through authentic, real-world projects (Almulla, 2020). Theoretically, PjBL is grounded in constructivism, which posits that knowledge is constructed through experience and social interaction (Piaget, 2008). Unlike traditional instructional models that primarily focus on the transmission of information (Granado-Alcón, 2020), PjBL positions students at the center of learning, actively engaging them in seeking solutions, designing strategies, and reflecting on learning outcomes. Several studies, such as Aziz and Nurachadijat (2023), have demonstrated that PjBL can enhance critical thinking and problem-solving skills, as students confront complex situations that require analysis, synthesis, and evaluation.

In practice, PjBL strongly emphasizes collaboration among students, which directly supports the development of problem-solving skills. Murniarti (2021) found that through group-based project work, students learn to identify problems, distribute tasks, and creatively integrate ideas. Vygotsky emphasized that learning is inherently a social process in which interaction with others—through discussion and observation—facilitates the development of higher-order thinking skills (Vygotsky, 1978). In the context of problem- or project-based learning, PBL/PjBL encourages collaboration and peer discussion, thereby fostering the development of analytical and problem-solving abilities. Hmelo-Silver (2004) further showed that such approaches make thinking strategies visible and trainable through group interaction. Historical reviews of collaborative learning also confirm strong theoretical foundations and empirical evidence that cooperation among learners strengthens learning through the exchange of perspectives, social scaffolding, and the negotiation of meaning—all of which are highly relevant to the effectiveness of PjBL (Yang, 2023).

Beyond collaboration, PjBL provides authentic learning experiences that have been shown to enhance students' motivation and engagement. Hidayat (2022) demonstrated that projects grounded in real-world contexts can stimulate curiosity, creativity, and students' initiative to seek solutions independently. These findings align with Deci and Ryan's (1985) intrinsic motivation theory, which asserts that when learners experience autonomy, competence, and relatedness in the learning process, their motivation tends to be stronger, more sustained, and of higher quality. Further empirical evidence is provided by the meta-analysis by Wijnia et al. (2024), which found that project- and problem-based learning positively impacts students' interest, enjoyment, and perceptions of task value. Thus, active engagement in authentic projects not only strengthens cognitive skills but also cultivates perseverance, responsibility, and intrinsic motivation that are essential for long-term learning success.

In addition to collaborative and authentic learning experiences, PjBL has also been proven effective in developing students' metacognitive skills. Research across various educational settings indicates that implementing PjBL—particularly when combined with reflective strategies—enhances students' ability to plan, monitor, and evaluate their own learning processes. Arifa et al. (2018) reported that following the application of PjBL, students' average metacognitive scores increased from Cycle I to Cycle II, indicating improved self-regulation of thinking. Similarly, Andriyatno (2024), in a study that integrated Project-Based Learning with the Sustainable Development Goals (SDGs), found a significant improvement in the planning indicator, a key component of students' metacognitive awareness. The combination of authentic experiences, collaboration, and internal reflection positions PjBL not merely as a method for developing cognitive and social skills, but also as an approach that equips students with introspective abilities—the capacity to evaluate their own thinking strategies, revise learning approaches, and enhance the quality of problem-solving in future contexts.

The effectiveness of PjBL in enhancing students' problem-solving skills can therefore be understood as the result of a synergy between constructivist principles, experiential learning through projects, and rich social interaction. Several empirical studies support this conclusion. Susanta (2022) found that PjBL significantly improved university students' problem-solving and critical-thinking skills compared with conventional instruction. Furthermore, among junior high school students, studies by Guo et al. (2020) and Ahmida et al. (2025) demonstrated that students who learned through Project-Based Learning on topics such as cubes and rectangular prisms showed greater improvements in mathematical problem-solving abilities than those in control groups. Literature reviews also emphasize that PjBL offers comprehensive benefits, not only in cognitive domains (analysis, synthesis, and problem solving) but also in affective and social domains, including motivation, collaboration, and responsibility (Dewi, 2022). Therefore, PjBL can be regarded as a holistic instructional approach in which cognitive, social, and affective dimensions converge to form more comprehensive problem-solving skills, highly relevant to 21st-century education, where critical, creative, and collaborative thinking are essential competencies.

CONCLUSION

The results of this study indicate that the Project-Based Learning model successfully improved the problem-solving skills of eleventh-grade students at SMA Negeri 2 Mataram in the topic of linear motion. The independent samples t-test revealed a significant difference between the pretest and posttest scores, with a calculated t-value of

−5.527 and a critical t-value of 2.000 at a 0.05 significance level. The increase in the mean score from 63.24 to 70.12 demonstrates that the implementation of PjBL was effective in encouraging students to think analytically, collaborate in groups, and connect physics concepts with real-world problems. These findings suggest that the PjBL model can serve as an alternative, creative instructional method to enhance the quality of physics education at the secondary school level. To foster more active, creative, and skillful problem-solving among students, teachers are encouraged to integrate project-based activities into their instructional practices. In addition, schools should support the implementation of Project-Based Learning by providing adequate facilities, sufficient instructional time, and professional development opportunities for teachers. Future researchers are advised to develop similar studies across different topics and educational levels, and to combine PjBL with STEM approaches or inquiry-based learning to broaden understanding of the model's effectiveness across various dimensions of 21st-century skills.

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