Project-based learning on pascal's law: A quasi-experimental study on problem-solving skills in environmental contexts

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Abstract
This study examined the effectiveness of a project-based learning (PjBL) module on Pascal's Law in improving students' problem-solving skills within environmental contexts. The research employed a non-equivalent control group pretest–posttest design involving two classes of grade XI students at a senior high school in Barito Kuala district. The study groups consisted of a control class (n=21) and an experimental class (n=22). Data were obtained through learning outcome tests and analyzed using normality and homogeneity tests, Mann-Whitney U test, and effect size calculation. The findings reveal that the PjBL module significantly enhanced students' problem-solving abilities. The most substantial improvements were observed in fact-finding and solution-finding, while moderate progress was identified in objective finding, problem finding, idea finding, and acceptance finding. The effect size reached 0.72 (medium). These findings indicate that the the PjBL module on Pascal's Law is effective in strengthening problem-solving skill while also fostering environmental awareness and higher-order thinking. The module thus provides an alternative learning resource to support contextual and skill-oriented physics education.

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1. Introduction

Physics is the study of natural phenomena through scientific approaches such as observation, measurement, and drawing conclusions based on empirical evidence (Gjerde et al., 2022). One of the key competencies students must master to face the challenges of the 21st century is problem-solving ability (Kurmawati et al., 2020). Physics learning that emphasizes the development of critical thinking and problem-solving skills can deepen conceptual understanding and enhance students' ability to apply knowledge in various contexts, including environmental issues (Baran et al., 2021).

However, students' problem-solving skills in Indonesia remain relatively low. The results of PISA (2022) showed a decline compared to 2018. Several existing empirical evidences consistently show that students' low problem-solving performance is characterized by difficulties in mathematical modeling (Gjerde et al., 2022; Solihin et al., 2024), contextual analysis (Musengimana et al., 2025; Sari et al., 2022; Zhu et al., 2023) and metacognitive engagement (Mufidah et al., 2025), which are heavily influenced by teaching practices that prioritize rote and procedural learning over the development of higher-order thinking skills (Lee et al., 2021).

One critical factor is the teaching modules used in schools. These modules are generally based on the Ministry of Education and Culture's format. However, the modules used in schools do not explicitly train problem-solving skills, which are part of higher-order thinking skills, nor do they integrate these skills with contextual wetland issues, such as fluid-related phenomena. The importance of contextual learning, particularly learning that connects with environmental issues, to foster students' critical and analytical thinking more effectively (Loyens et al., 2023).

To address this issue, Project-Based Learning (PjBL) offers a promising solution. This model engages students as active participants in completing projects that train problem-solving skills in real-world contexts (Karan & Brown, 2022; Kurt & Akoglu, 2023). Previous studies support its effectiveness found that PjBL was more effective in improving mathematical problem-solving skills compared to conventional methods (Loyens et al., 2023; Suciawati et al., 2022); PBL-based modules improved students' problem-solving skills in more applicable contexts (Guo et al., 2020; Li & Ma, 2024; Safran & Asdarina, 2024), and real projects help students sharpen their analytical and problem-solving abilities (Garita, 2023; Zhang & Ma, 2023).

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Nevertheless, the development of PjBL-based teaching modules integrated with environmental issues in specific physics topics, such as Pascal's Law, is still rarely conducted. However, the development of PjBL-based teaching modules that integrate environmental issues in specific physics topics, such as Pascal's Law, is still rare. This is because the teaching modules used in schools are primarily sourced from the Ministry of Primary and Secondary Education of the Republic of Indonesia. They have not been specifically developed to integrate environmental issues such as wetlands. Yet, this topic is highly relevant to daily life and holds strong potential as a learning context. Therefore, this study aims to analyze the effectiveness and achievement of problem-solving indicators through the development of PjBL-based teaching modules on Pascal's Law. Pascal's Law underpins the use of hydraulic systems to lift and stabilize houses in flood-prone areas and supports disaster response equipment capable of lifting, cutting, and stabilizing collapsed structures effectively. The application of this principle enhances the resilience of the built environment to inundation and structural damage risks associated with climate change. With this model, students' higher-order thinking and problem-solving skills are expected to improve significantly while simultaneously fostering environmental awareness.

2. Method

This study was a quasi-experimental study. Participants were 43 students at a senior high school in Barito Kuala Regency. Saturated sampling was used for the sample, which was divided into two classes: an experimental class and a control class. The control class (XI-A) consisted of 21 students, and the experimental class (XI-B) consisted of 22 students. The researchers used existing classes at the school, resulting in limited randomization. Therefore, this study employed a non-equivalent control group pretest-posttest design. The research design is shown in Table 1.

Table 1. Non-equivalent control group pretest-posttest design

Subject	Pretest	Treatment	Posttest
Experiment	O_1	X	O_2
Control	O_3	-	O_4

O_1 = pretest of experimental class
O_3 = pretest of control class
O_2 = posttest of experimental class
O_4 = posttest of control class
X = treatment using a Pascal's Law teaching module based on Project-Based Learning

The study was carried out, from Agustus 2024 to May of the 2025. The implementation of the teaching module using PjBL was conducted from April to May 2025, spanning five meetings. Each meeting lasted 2 x 45 minutes. In the experimental class, a pretest was administered to students at the first meeting. At the second meeting, the PjBL-based teaching module was implemented. This second meeting covered the first to third phases of the PjBL model (determining basic questions, designing product planning, and preparing a schedule). At the third meeting, the fourth phase of the PjBL model was applied (monitoring the activity and development of the project), and the fifth and sixth phases (testing results and evaluating learning experiences) were carried out at the fourth meeting. The fifth meeting was dedicated to the post-test. In the control class, a pretest was also administered at the first meeting. The second meeting involved learning using the lecture method. At the third meeting, students were given worksheets. At the fourth meeting, practice questions were provided. The fifth meeting was the post-test activity. The teacher who taught both the control and experimental classes was the same physics teacher.

The teaching module developed in this study was designed by integrating learning objectives, content, strategies, and assessment into a coherent framework. Each component was structured to meet students' needs and align with the Merdeka Curriculum, ensuring support for achieving learning goals that emphasize higher-order thinking skills. Specifically, this module applies PjBL. to the topic of Pascal's Law, with a focus on fostering students' problem-solving skills in environmental contexts.

The general information component includes module identity (author, school level, subject, class, phase, semester, topic, and allocated time), as well as prerequisite competencies required before studying static fluids. It also presents the Pancasila Student Profile, available learning facilities, characteristics of the targeted learners, and the project-based learning model employed. This systematic structure is intended to facilitate teachers in planning and implementing contextual learning aligned with both student needs and subject characteristics (Widya et al., 2021). The core components of the module consist of learning outcomes and objectives, meaningful understanding, essential questions, learning activities, and assessments. These elements were deliberately designed to train students' problem-solving skills based on specific indicators. As a result, the module emphasizes not only conceptual mastery but also the application of knowledge to real-world and environmentally related issues (Widya et al., 2021). The appendix includes Student Worksheet, teaching materials, enrichment and remedial activities, a glossary, and references. The worksheets integrate aspects of the Pancasila Student Profile, particularly collaboration and critical reasoning.

The data collection instrument was a learning achievement test consisting of three items. The questions were developed based on Osborne-Parnes' problem-solving skills indicators (Price et al., 2021). The questions were validated by three validators and were categorized as highly valid (3.71). The reliability coefficient (Cronbach's alpha) was found to be acceptable (0.53). The test specifications are shown in Table 2.

Table 2. Questions specifications

Goals	Questions	Score
Students are able to evaluate Pascal's law in making a hydraulic jack project.	Read the description carefully, understand the question, and answer correctly! In several situations, such as avoiding floods, repairing foundations, or adding a new floor beneath a building, houses need to be elevated. One of the most effective solutions is using a hydraulic jack. This jack works based on Pascal's law, which states that pressure applied to a fluid in a closed space is transmitted equally in all directions. This principle allows heavy loads to be lifted with relatively small forces, as long as the pressure is transmitted through the fluid to a larger component. A house weighing 10,000 Newtons is planned to be elevated. The hydraulic jack used consists of two cylinders with different cross-sectional areas. The small cylinder has a cross-sectional area of 10 cm^2, while the large cylinder has a cross-sectional area of 200 cm^2. Based on the ratio of these areas, the force applied to the small cylinder will be transmitted and amplified in the large cylinder, enabling the house to be lifted. However, challenges arise in calculating the force that must be applied to the small cylinder for the system to work optimally. In addition, the system's efficiency is also influenced by factors such as changes in cross-sectional area, pressure within the system, and fluid stability. Moreover, hydraulic jacks have both advantages and disadvantages in real applications. Therefore, in-depth analysis is required to ensure that this system can be relied upon in real situations. After reading the above description, apply your understanding to answer the following questions based on Pascal's law and the given situation: Questions: a. In your opinion, what are the challenges faced in the process of lifting a house using a hydraulic jack? b. What information from the situation do you think is influential? c. What problems might arise in the implementation of this method? d. What ideas might be proposed to solve these problems? e. Find the main solution based on the problems encountered. f. What are the advantages and disadvantages of the proposed solution?	30
Students can analyze the relationship between Pascal's law and project activities.	Observe the following picture!  Berita Kalsel Rumah Kayu Terendam Banjir di Kalsel Bisa Ditinggikan, Diperlukan 20 Orang dan 100 Alat Dongkrak Editor: Fathurahman https://kalteng.tribunnews.com/2023/02/27/rumah-kayu-terendam-banjir-di-kalsel-bisa-ditinggikan-diperlukan-20-orang-dan-100-alat-dongkrak Flooding in South Kalimantan has caused many wooden houses to be submerged, resulting in damage and discomfort for their inhabitants. To address this issue, one proposed solution is to elevate the houses using hydraulic jacks. However, the implementation of this method faces several significant challenges. The house-lifting process requires a considerable workforce. Approximately 20 people are needed to carry out this task effectively. In addition, the availability of hydraulic jacks is a major obstacle. To lift houses efficiently, around 100 jacks are required. The limited number of tools can hinder the mass lifting process. Moreover, lifting houses requires specific skills and experience in operating hydraulic jacks. A lack of trained workers may affect both the effectiveness and safety of the process. The flooded locations of the houses also complicate the lifting operation, requiring adjustments in methods and equipment to overcome these challenges. The procurement of jacks, labor, and other logistics also incurs substantial costs, and budget limitations may restrict the wide-scale implementation of this solution. Overcoming these challenges requires careful planning, coordination among various stakeholders, and sufficient resources to ensure the process can be carried out effectively and efficiently. In facing these challenges, it is essential to involve multiple stakeholders, including the government, the community, and the private sector, in flood mitigation and house-lifting efforts. Strong collaboration among all parties will accelerate recovery and ensure the sustainability of the solutions implemented. Furthermore, training for local workers is necessary to improve their skills in operating hydraulic jacks. This will not only accelerate the lifting process but also enhance the human	30

Goals	Questions	Score
	resource capacity in the region. It is also important to consider the use of technology and innovation in the lifting process. For instance, the use of automatic or semi-automatic jacks could reduce reliance on manual labor and increase efficiency. Additionally, well-planned logistics and distribution of hydraulic jacks are crucial. Ensuring that the tools are available in the right locations and in sufficient numbers will help prevent delays in the lifting process. Regular evaluation and monitoring of the house-lifting process should also be conducted to ensure the effectiveness of the solutions implemented and their alignment with community needs. Thus, it is expected that the flooded houses can be elevated promptly and re-inhabited by their owners. Questions: a. What challenges are faced in lifting houses using hydraulic jacks? b. What facts are presented in the problem orientation above? c. What problem statement can be formulated? d. What ideas can be proposed to solve the problem? e. What solution can be determined based on the proposed ideas? f. What are the strengths and weaknesses of the determined solution?	
Students are able to design the application of Pascal's law, namely hydraulic pumps	Challenge Description: Didi and his team from SMAN 1 Anjir Muara are developing a science project that utilizes simple hydraulic technology to create a hydraulic jack using easily obtainable materials such as popsicle sticks and medical syringes. The project aims to demonstrate how the basic principle of Pascal's Law can be applied in real life to lift heavy loads. In this project, the hydraulic jack is designed to lift a miniature house weighing 14 Newtons as a simulation of using a hydraulic jack to lift a real house. The hydraulic jack system is built using two medical syringes of different diameters. The smaller syringe, with a diameter of 10 cm, is used as the actuator, while the larger syringe, with a diameter of 20 cm, is used to lift the load. Both syringes are connected by a plastic tube filled with fluid. When pressure is applied to the smaller syringe, the pressure is transmitted through the fluid to the larger syringe, generating greater force to lift the miniature house. However, this project faces several technical and design challenges. The first challenge is ensuring that the system can generate sufficient pressure in the smaller syringe to lift the miniature house without causing leaks or damage to the medical syringes or the popsicle stick frame. In addition, the frame made of popsicle sticks must be strong and stable enough to support the larger syringe and the miniature house without breaking or shifting. Another challenge is to ensure that the diameter difference between the small and large syringes is accurately calculated so that the system operates in accordance with Pascal's Law. The use of simple materials such as popsicle sticks and hot glue also poses a risk of structural failure, especially if the system's pressure becomes too high. Furthermore, the team must consider the possibility of fluid leakage from the tube connections or syringes, which could reduce system efficiency. As part of the development process, Didi and his team must design and test the hydraulic jack to ensure its stability and reliability. They also need to find ways to reinforce the popsicle stick frame without reducing flexibility or significantly increasing project costs. Based on the challenges and issues described regarding the use of a hydraulic jack to lift houses submerged in floods, design an innovative solution based on Pascal's Law and the given situation: Questions: a. After reading the description above, in your opinion, what challenges are faced? b. What information do you think is relevant to the situation? c. What problems might arise, in your view? d. What ideas could be developed to solve these problems? e. Identify the main solution based on the problems encountered. f. What are the advantages and disadvantages of the proposed solution?	40

Data were analyzed using several steps:

a. Normality tests were conducted to verify data distribution on the pretest and posttest results from the experimental and control classes.
b. A homogeneity test was conducted subsequently to confirm the equality of variance between the experimental and control classes.
c. If the data were normally distributed, a t-test was used to test the hypothesis; conversely, if the data were not normally distributed, a Mann-Whitney U test was employed.
d. Effect size was then calculated using Cohen's d, corrected for sample size using Equation (1). This coefficient estimates the effect size and provides practical significance, complementing the results of non-parametric tests.

$$\text{Unbiased estimate of } (d_{kor}) \cong dx\ 1 - \frac{3}{(4N_E + N_C - 9)} \quad (1)$$

N_E = number of experimental class data, N_C = number of control class data.

The effect size results were then adjusted to the effectiveness criteria shown in Table 2.

Table 3. Effect size criteria

Effect Size (d_{kor})	Category
$0.0 \leq d_{kor} < 0.2$	Low
$0.2 \leq d_{kor} < 0.8$	Medium
$0.8 \leq d_{kor} < 2$	High

(Taylor & Alanazi, 2023)

Furthermore, students' problem-solving skills were analyzed based on the learning test results. The results were then categorized based on the criteria in Table 4.

Table 4. Criteria for problem-solving skills

Range	Criteria
>80	Very Good (VG)
>60-80	Good (G)
>40-60	Fairly Good (FG)
>20-40	Poor (P)
≤20	Very Poor (VP)

(Widoyoko, 2015)

3. Results and Discussion

3.1. Results

Table 5 presents the results of the descriptive statistical analysis of the average scores in the experimental and control classes. The data reflect student achievement after implementing PjBL on Pascal's Law material.

Table 5. Pretest-posttest descriptive statistics

Learning Outcomes	N	Mean Pretest	Standar deviation	Mean Posttest	Standar deviation
Experimental	22	9.86	4.38	59.41	12.64
Control	21	10.10	3.62	51.29	9.80

The statistical test results for the control and experimental classes are presented in Table 5. The normality test results indicate that the data in the experimental class were normally distributed, whereas the data in the control class were not normally distributed. The homogeneity test showed that both datasets were homogeneous. Since one dataset was not normally distributed, hypothesis testing proceeded using the non-parametric Mann–Whitney U test.

Table 6. Statistical test results

Learning Outcomes	N	Normality Test (Sig)	Homogeneity Test (Sig)	Mann-Whitney U Test (Sig 2-tailed)
Experimental	22	0.099	0.246	0.011
Control	21	0.010		

The use of PjBL-based teaching modules demonstrated an effect size of 0.12 on students' problem-solving skills, based on the average pretest and post-test scores of the experimental and control classes. These results are shown in Table 7.

Table 7. Results of effect size analysis

$\bar{X}$experiment	$\bar{X}$control	$\lvert\bar{X}_{exp} - \bar{X}_{cont}\rvert$	S_{exp}	S_{cont}	Pooled SD	Effect Size (d)	Correction Factor	d_{kor}
49.55	41.19	8.36	12.95	9.26	11.30	0.74	0.97	0.72

Table 8 presents the students' problem-solving skill achievements in the experimental and control classes. Almost all pretest indicators in both the experimental and control classes were categorized as very poor, except for the objective finding indicator, which was categorized as poor. Based on the experimental class posttest results, two indicators were categorized as good and four indicators were categorized as fairly good. In the control class, all indicators were categorized as fairly good.

Table 8. Achievement of students' problem-solving skills

Indicator	Experiment		Control	
	PreTest	PostTest	PreTest	PostTest
Objective Finding	20.60 (P)	60.00 (FG)	20.46 (P)	55.35 (FG)
Fact Finding	16.66(VP)	68.08 (G)	17.88 (VP)	59.15 (FG)
Problem Finding	8.25 (VP)	58.86 (FG)	7.93 (VP)	52.69 (FG)
Idea Finding	4.24 (VP)	43.33 (FG)	8.88 (VP)	56.19 (FG)
Solution Finding	3.63 (VP)	66.96 (G)	4.76 (VP)	46.34 (FG)
Acceptance Finding	1.31 (VP)	51.51 (FG)	2.11 (VP)	44.30 (FG)

3.2. Discussions

This study used a pretest–posttest design to assess the effect of the PjBL-based learning module on students' problem-solving abilities. The comparison of pretest and posttest results for the experimental and control groups was intended to provide a clearer picture of the effectiveness of the PjBL-based learning module compared to conventional teaching approaches. The pretest measured initial knowledge and problem-solving skills before the intervention, while the posttest evaluated students' abilities after the experimental group used the PjBL module and the control group received conventional learning. Initial pretest results indicated that both groups had relatively equivalent basic abilities. This equivalence is important because it ensures that any differences in posttest scores can be attributed to the learning method applied, rather than to variations in students' initial abilities. The equivalence of the pretest results strengthens the validity of the post-intervention comparison because it indicates that both groups had almost the same initial abilities in physics problem-solving skills before the treatment was administered (Harudu et al., 2024; Liliawati & Hasanah, 2023).

Following the intervention (see Table 5), posttest scores were used to evaluate the progress of problem-solving skills between the two study groups. The experimental group, which received the Project-Based Learning (PjBL) module, showed significant improvement. Their average posttest score reached 59.41 (SD = 12.65), representing a significant increase of 49.55 points from the initial pretest score, indicating the successful implementation of the PjBL module. Meanwhile, the control group, which received conventional learning, also experienced improvement, reaching an average score of 51.29 (SD = 9.80), or approximately 41.19 points from the initial score. Despite this improvement, the results achieved by the control group were still lower than those of the experimental group.

According to Table 6, the Mann–Whitney U test produced a significance value (2-tailed) of 0.011, which is smaller than 0.05 (sig < 0.05). This result leads to the rejection of Ho and acceptance of Ha, indicating a significant difference between the learning outcomes of the experimental and control classes. This difference occurred because the experimental class received treatment using the developed teaching module. Teaching modules based on the Project-Based Learning (PjBL) model, which emphasizes problem-solving through projects, produces significant differences compared to classes without such treatment (Husniyah et al., 2016; Liliawati & Hasanah, 2023).

Following the Mann–Whitney U test, an effect size calculation with a correction factor was conducted to measure the magnitude of influence on student learning outcomes in both classes. As shown in Table 7, the corrected effect size for the experimental and control classes fell within the medium effect category, with a value of 0.72. The larger effect size demonstrates the substantial impact of the independent variable here, the developed product on the dependent variables of learning outcomes and problem-solving skills (Anggraini et al., 2022; Nugroho et al., 2020). The average effect of PjBL on student learning outcomes is both large and significant, with the model enhancing creativity and critical thinking in problem solving (Tafakur et al., 2023).

According Table 8, the results of the pretest and posttest indicated improvements across all indicators in both the experimental and control classes, with the highest achievements observed in the experimental class. Two indicators in the experimental class reached the “good” category, namely fact finding, and solution finding. This improvement occurred because project-based learning (PjBL) encouraged students to actively search for data and formulate solutions based on direct experience during the hydraulic jack project. students actively seek data from multiple sources to strengthen their understanding and solutions in PjBL (Baran et al., 2021). The trial-and-error process in project work helps students test and select the most effective solutions Similarly (Alrajeh, 2021). Students are guided to work cooperatively in groups while also engaging in critical thinking through the analysis of information from multiple sources. This design reflects the principles of the Merdeka Curriculum, which prioritizes student-centered learning with teachers serving as facilitators (Widya et al., 2021).

The other four indicators objective finding, problem finding, idea finding, and acceptance finding were categorized as “fairly good”. The moderate increase in objective finding suggests that PjBL assisted students in identifying goals more accurately, though not yet fully optimally. PjBL can encourage students to engage actively in observing their environment and clearly formulating problems as an initial step in problem-solving skills

(Kanyesigye et al., 2023). The problem finding indicator also showed that PjBL helped students identify problems more effectively, although still not maximally. Exploratory activities in PjBL train students to independently recognize gaps in complex problems (Liliawati & Hasanah, 2023).

In idea finding, the control class scored slightly higher because students were freer to explore ideas without being tied to a project, whereas in the experimental class, ideas were more focused on the hydraulic jack project. Designing projects in PjBL stimulates students' creative thinking in generating alternative solutions (Baran et al., 2021). Meanwhile, in acceptance finding, students began to demonstrate the ability to evaluate solutions under developed conditions, though reinforcement is still needed. Final project evaluations in PjBL enhance students' ability to evaluate realistic solutions (Samsudin et al., 2020).

In the objective findings indicator, the pretest results showed that students in both the experimental and control classes still performed poorly, as they tended to write general objectives without addressing the core of the problem. For example, in the question about the flooding phenomenon in South Kalimantan, which has submerged residents' houses, students are still unable to identify the challenges that need to be addressed, such as determining the minimum force on a small cylinder or assessing the impact of changes in cross-sectional area. After the learning process, the experimental class showed significant improvement in goal formulation; however, the level of detail and accuracy did not fully surpass that of the control class, which demonstrated clearer and more relevant goal formulation. Goal clarity and accuracy directly influence learning effectiveness by increasing focus and supporting the monitoring of learning progress (Urhahne & Wijnia, 2023). Students in the experimental class, who initially had limited ability to identify the core objectives of the problem, demonstrated substantial improvement in the posttest, reflected in their enhanced ability to determine the focus of problem-solving, whereas the control class showed only relatively small improvements. This difference indicates that learning in the experimental class was more effective in developing goal formulation skills. Without structured guidance, student-formulated goals tend to be less meaningful and less effective in supporting the problem-solving process (Gjerde et al., 2022; Locke, 2015).

In the fact finding indicator, the pretest phase showed that students in both the experimental and control classes had low ability to identify facts, as indicated by their tendency to ignore important information and to mix relevant facts with irrelevant ones. For example, in the first question, most students were unable to identify the supporting information, such as calculating the required force and determining changes in the hydraulic cross-sectional area. After the learning process, both classes showed improvement in gathering relevant information, with the improvement in the experimental class appearing more significant. Implementation of project-based learning can improve understanding of core concepts, scientific thinking skills, and the ability to analyze and select relevant information to support problem-solving (Kurt & Akoglu, 2023; Zhao & Wang, 2022). The experimental class showed significant improvement in fact identification after the intervention, reflected in students' increased ability to recognize key facts, while the control class experienced only limited improvement. Project-Based Learning not only improves students' perceptions of learning but also their actual ability to design solutions based on valid data and facts (Crawford et al., 2024; Guo et al., 2020b). The implementation of PjBL effectively increased motivation, creativity, and mastery of the material, making it easier for students to identify core facts from complex information (Pan et al., 2023).

For the Problem-Finding indicator, the pretest results showed that most students in both the experimental and control classes had difficulty identifying core problems, as reflected in their low ability to formulate problems accurately. For example, in the second question about a visual illustration of a house submerged in a flood and the process of lifting it using a hydraulic jack. Most students are not yet able to identify the problem, such as how the process of lifting a house using a hydraulic pump can be carried out safely, efficiently, and in accordance with safety standards. After the learning process, both groups improved; however, the experimental class showed a sharper improvement, demonstrating better and more focused ability to select relevant information and identify the root causes of problems. Although the control class also showed progress, its achievement remained at a suboptimal level. Project-Based Learning effectively encourages students to recognize and formulate problems creatively and accurately in real-life contexts (Garita, 2023; Ndiung & Menggo, 2024). PjBL helps students analyze and understand the roots of problems through a contextual and practical approach (Afriana et al., 2016; Latifah et al., 2020). Therefore, the treatment in the experimental class proved more effective in improving problem-finding skills.

In the idea finding indicator, pretest results showed that students in both the experimental and control classes had a low ability to generate alternative solutions, as evidenced by the limited number and variety of ideas proposed. For example, in the second question, most students were unable to generate ideas, such as using a more affordable and easy-to-build jack made from local materials. After the learning process, the experimental class showed significant improvement, demonstrating the ability to generate more diverse and original ideas, while the control class tended to provide more limited responses. Project-Based Learning significantly develops students' creative thinking dimensions, including fluency, flexibility, originality, and elaboration (Guo et al., 2020b; Kurt & Akoglu, 2023; Lavli & Efendi, 2024). The increase in posttest scores in the experimental class reflects growth in the creativity and diversity of proposed ideas, whereas the improvement in the control class

was relatively smaller, indicating that the learning strategy used in the experimental class was more effective in stimulating creative idea generation.

In the solution finding indicator, students in both classes showed difficulty in determining appropriate solutions before the learning process. For example, in the third question, which asked students to design a practical project to construct a miniature hydraulic jack using simple materials such as ice cream sticks, medical syringes, and plastic tubing, most students were unable to design such a hydraulic jack. After the learning process, the experimental class demonstrated more significant improvement, as indicated by students' ability to generate more relevant solutions supported by logical reasoning and to consider the feasibility and impact of the solutions. In contrast, the control class tended to provide more general and less in-depth responses. Pretest results showed that students' initial ability to distinguish between effective and ineffective alternative solutions was still weak; however, posttest scores in the experimental class increased sharply, indicating strong development in their ability to evaluate and select the best solutions. Although the control class also experienced improvement, their results remained below those of the experimental class. Project-Based Learning provides students with opportunities to critically analyze and synthesize information (Guo et al., 2020b; Sutrio et al., 2024), and PjBL strengthens students' ability to solve problems systematically and select logical solutions (Garita, 2023; Gjerde et al., 2022).

In the acceptance findings indicator, pretest results showed that students in both classes had very limited ability to consider the feasibility and acceptability of solutions. For example, regarding the third question, most students failed to identify the advantages of their design, including its ease of modification and the relatively low cost of the materials. In the posttest, both groups improved; however, the experimental class showed more significant progress, marked by an increased ability to evaluate, conclude, and accept the most appropriate solutions. In contrast, the control class, although able to explain the application of solutions more systematically, still showed limitations in formulating adequate conclusions. The pretest results in the experimental class indicated that students were not yet accustomed to assessing solutions objectively; however, after the learning process, posttest scores increased significantly, indicating that students became increasingly able to assess the feasibility, relevance, and practical impact of solutions. Meanwhile, the improvement in the control class was relatively smaller. authentic and contextual Project-Based Learning designs play a crucial role in encouraging students to critically evaluate the feasibility, relevance, and practical impact of the resulting solutions (Guo et al., 2020b; Kurt & Akoglu, 2023; Sánchez-García & Reyes-de-Cózar, 2025).

The findings of this study indicate that project-based learning modules are more effective than conventional instruction in improving students' problem-solving skills. Authentic project activities, such as building a simple hydraulic jack, deepen students' understanding of Pascal's Law while also promoting the application of physics concepts in real-world contexts. Furthermore, the Osborn–Parnes framework supports systematic thinking and has the potential to serve as a strong foundation for developing learning modules oriented toward higher-order thinking skills.

4. Conclusion

Based on the trial results, improvements were observed across all indicators of problem-solving skills, with fact finding and solution finding reaching the "good" category, while objective finding, problem finding, idea finding, and acceptance finding fell within the "fair" category. The effectiveness of the project-based learning module was further confirmed through statistical testing and effect size analysis, which indicated a medium effect. Therefore, this module is considered effective and can serve as an alternative project-based learning approach that supports the development of 21st-century skills. These findings highlight that integrating the project-based learning model into teaching modules provides a relevant and effective approach to enhancing students' problem-solving abilities. To further examine its generalizability and strengthen evidence of effectiveness, future studies are encouraged to involve larger and more diverse samples from schools with varying characteristics.

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Data Availability

The datasets generated during and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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