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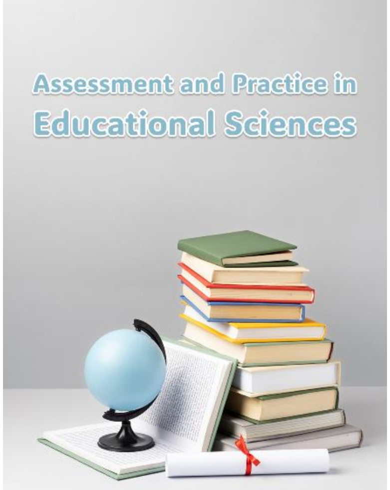

Investigating the Effectiveness of Physics Education Using the Phenomenon-Based Learning (PBL) Method Compared with the Traditional Method

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ABSTRACT

The present study aimed to investigate the effectiveness of physics education using the Phenomenon-Based Learning (PBL) method compared with the traditional teaching method on the academic achievement, understanding, application, and problem-solving ability of tenth-grade high school students in physics. The present research was a quasi-experimental study using a pre-test–post-test design with an experimental and a control group. The statistical population consisted of all tenth-grade female high school students, among whom 40 students were selected through cluster sampling and randomly assigned into experimental and control groups. The experimental group received physics instruction through the phenomenon-based learning (PBL) method using toys, simple experiments, and practical demonstrations, whereas the control group was taught through the traditional method. Data were collected using a researcher-made academic achievement test consisting of 12 descriptive questions measuring understanding, application, and problem-solving abilities. Content validity was confirmed by experts and teachers, and reliability was established using the split-half method with a coefficient of 0.74. Data analysis was conducted using descriptive statistics, Kolmogorov–Smirnov tests, Levene's test, and analysis of covariance (ANCOVA). The findings demonstrated that the PBL method significantly improved students' academic achievement compared with the traditional method ($F=20.119$, $p=0.001$, $\eta^2=0.352$). In addition, students in the experimental group showed significantly higher levels of understanding and comprehension of physics concepts than students in the control group ($F=4.793$, $p=0.035$, $\eta^2=0.115$). The PBL method also significantly enhanced students' ability to apply physics concepts in everyday life ($F=7.723$, $p=0.009$, $\eta^2=0.173$). Furthermore, a significant difference was observed between the two groups regarding problem-solving ability, favoring the phenomenon-based learning approach ($F=8.588$, $p=0.006$, $\eta^2=0.188$). The assumptions of normality, homogeneity of variances, and homogeneity of regression slopes were satisfied prior to conducting ANCOVA. The results of the study indicate that teaching physics through the phenomenon-based learning method is more effective than the traditional method in improving students' academic achievement, conceptual understanding, application of physics in real-life situations, and problem-solving skills. The use of toys, simple experiments, and observable phenomena increased students' engagement, motivation, and comprehension of abstract physics concepts. Therefore, integrating phenomenon-based learning activities into physics classrooms can provide a more meaningful, attractive, and practical learning environment for students.

Keywords: Phenomenon-Based Learning (PBL), Physics Education, Academic Achievement, Problem Solving, Conceptual Understanding, Traditional Method

Introduction

Education systems in the twenty-first century are increasingly expected to prepare learners not only for academic success, but also for problem solving, creativity, critical thinking, and the application of knowledge in real-world situations. Rapid scientific and technological developments have transformed educational expectations and emphasized the necessity of adopting learner-centered instructional approaches capable of connecting theoretical concepts with practical experiences. Traditional educational systems, which are primarily based on memorization and teacher-centered instruction, are often unable to meet these emerging educational demands. Consequently, modern educational paradigms increasingly emphasize active learning, collaborative engagement, inquiry-based instruction, and contextualized teaching methods that enhance students' conceptual understanding and practical competencies (1-3). In science education, particularly in physics instruction, these challenges become even more significant because physics is inherently abstract and conceptually demanding. Many students perceive physics as difficult, highly mathematical, disconnected from everyday life, and lacking practical relevance, which often leads to reduced motivation and poor academic performance (4).

Physics education has long been recognized as one of the most challenging domains in school curricula because effective learning in physics requires more than memorization of formulas and definitions. Students must develop the ability to understand physical phenomena, analyze relationships between variables, apply scientific principles in practical situations, and solve unfamiliar problems using conceptual reasoning. Traditional lecture-based approaches generally emphasize transferring information from teacher to student without providing opportunities for active exploration or experiential learning. As a result, many students fail to develop deep conceptual understanding and often experience difficulties in transferring learned concepts to real-world contexts (4). Research in educational psychology also suggests that meaningful learning occurs when learners actively interact with educational content, construct knowledge through experience, and establish connections between prior knowledge and new information (5). Therefore, modern approaches to physics education increasingly emphasize active participation, collaborative inquiry, experimentation, and contextualized learning environments.

One of the approaches that has recently received considerable attention in science and physics education is Problem-Based Learning (PBL) and its related phenomenon-based instructional approaches. Phenomenon-based learning focuses on engaging students with real-world phenomena, observable events, practical problems, and authentic situations that stimulate curiosity and encourage students to actively investigate scientific concepts. Instead of passively receiving information, learners become active participants in the educational process through observation, experimentation, discussion, and collaborative problem solving. This educational model aims to create deeper conceptual understanding by connecting theoretical knowledge with everyday experiences and practical applications (6). Phenomenon-based learning also supports interdisciplinary thinking because learners are encouraged to analyze complex situations from multiple perspectives while integrating different forms of knowledge.

Educational theorists argue that learning becomes more effective when instructional experiences stimulate curiosity, exploration, and intrinsic motivation. Activities involving games, toys, simple experiments, and practical demonstrations can significantly increase students' engagement and cognitive participation in classroom activities. In this regard, playful and interactive educational experiences are increasingly recognized as effective pedagogical tools that improve conceptual understanding, retention of knowledge, and student motivation (7, 8). The use of playful pedagogical strategies enables learners to experience educational content in a less stressful and more stimulating environment, thereby increasing willingness to participate and facilitating active knowledge construction. In physics education specifically, toys, demonstrations, and practical experiments can transform abstract concepts into observable and understandable experiences that improve students' comprehension and application of scientific principles.

Recent empirical studies have provided strong evidence supporting the effectiveness of PBL and phenomenon-based approaches in science education. A meta-analysis conducted by Dewi et al. demonstrated that the implementation of the Problem-Based Learning model significantly improved students' problem-solving abilities in physics courses, particularly in practical and application-oriented topics such as heat and temperature (9). Similarly, Halim's systematic review of studies related to PBL in physics education concluded that the majority of empirical investigations reported positive effects on students' higher-order thinking skills, conceptual understanding, critical thinking, and engagement in learning activities (6). These findings suggest that learner-centered and inquiry-based approaches can significantly improve educational outcomes compared with conventional lecture-based instruction.

Several studies have also highlighted the role of technology-enhanced and simulation-assisted PBL models in improving physics learning outcomes. Molamahu et al. reported that the integration of PhET simulations with the PBL model significantly enhanced students' learning outcomes in physics compared with traditional instruction (10). Likewise, Dewi and Nisa found that PBL instruction supported by electronic live worksheets produced substantial improvements in students' critical thinking skills and conceptual mastery in physics learning environments (11). These findings indicate that combining practical and interactive activities with problem-centered instruction creates more meaningful and engaging learning experiences for students.

Another important dimension of PBL approaches is their contribution to scientific literacy and collaborative learning. Karmila et al. found that Problem-Based Learning integrated with Google Classroom significantly improved students' scientific literacy in physics education (12). This suggests that modern educational technologies can complement active learning strategies and further strengthen students' ability to interpret, analyze, and apply scientific concepts in authentic contexts. Similarly, Suharno et al. demonstrated that physics modules designed according to the PBL framework significantly enhanced students' critical and creative thinking abilities (13). Such findings are highly relevant because modern educational systems increasingly prioritize higher-order cognitive skills and creative problem solving over simple memorization of factual information.

Research has also demonstrated that PBL approaches positively influence students' academic achievement and attitudes toward learning physics. Bedemo reported that students exposed to Problem-Based Learning in mechanics courses achieved significantly higher academic performance and developed more positive attitudes toward physics compared with students taught using traditional methods (14). Likewise, Argaw et al. found that PBL instruction significantly improved students' motivation and problem-solving abilities in physics education (15). These findings suggest that learner-centered instructional methods not only improve cognitive outcomes but also enhance affective dimensions of learning, including motivation, confidence, and engagement.

The effectiveness of phenomenon-based and playful learning strategies has also been supported in educational contexts beyond physics instruction. Cano and Lomibao demonstrated that phenomenon-based learning videos significantly improved students' self-efficacy, reasoning abilities, mathematical problem solving, and academic achievement (16). Similarly, Li et al. reported that playful pedagogical activities produced better educational outcomes than traditional methods in language learning environments (8). These findings collectively indicate that interactive and learner-centered pedagogies can be effectively applied across multiple disciplines to enhance learning quality and student participation.

Despite the growing body of evidence supporting active learning approaches, traditional teaching methods continue to dominate many educational settings, particularly in physics classrooms. Traditional instruction often relies heavily on lectures, memorization, and repetitive exercises, which may limit students' opportunities for exploration, experimentation, and conceptual reasoning. While traditional methods can efficiently deliver large amounts of information, they may not adequately support the development of deep understanding, critical thinking, and practical problem-solving skills (1). Furthermore, the increasing integration of blended learning and digital education has highlighted the importance of combining innovative instructional strategies with traditional educational practices in order to maximize educational effectiveness (2, 3).

Considering the importance of improving conceptual understanding and practical application in physics education, there is a clear need for empirical studies examining the effectiveness of phenomenon-based instructional methods in comparison with conventional approaches. Although previous studies have demonstrated the benefits of PBL and related pedagogies, fewer studies have specifically investigated the combined use of toys, simple experiments, and observable phenomena in secondary school physics education. Moreover, many educational systems still rely predominantly on teacher-centered approaches despite increasing evidence supporting active learning strategies. Therefore, further investigation is necessary to determine whether phenomenon-based instruction can significantly improve students' academic achievement, conceptual understanding, application of physics principles, and problem-solving abilities in real classroom environments.

Accordingly, the present study aimed to investigate the effectiveness of teaching physics using the Phenomenon-Based Learning (PBL) method compared with the traditional teaching method on the academic achievement, understanding, application, and problem-solving ability of tenth-grade high school students.

Methods and Materials

The present study was conducted using a quasi-experimental research design with a pre-test–post-test structure including an experimental group and a control group. The purpose of the study was to investigate the effectiveness of physics education using the Phenomenon-Based Learning (PBL) method compared with the traditional teaching method on students' academic achievement and learning outcomes in physics. In this design, the dependent variables were measured before and after the implementation of the educational intervention in both groups. The independent variable consisted of physics instruction through the phenomenon-based learning method, which emphasized the use of toys, simple experiments, practical demonstrations, and observable phenomena to facilitate conceptual understanding and student engagement. The control group received instruction through the conventional teacher-centered approach routinely used in schools.

The statistical population of the study consisted of all tenth-grade female high school students. From this population, a sample of 40 students was selected using cluster sampling. Two classes were randomly selected from the available tenth-grade classes and were then randomly assigned to either the experimental group or the control group, with each group consisting of 20 students. The experimental group participated in physics lessons designed according to the phenomenon-based learning approach, while the control group continued learning through the traditional instructional method. To reduce the effects of extraneous variables and increase internal validity, students were not informed about the specific objectives of the study. Furthermore, the educational intervention was implemented within the normal classroom environment without altering the natural educational setting. Intelligence level and mathematics scores were also considered control variables due to their potential influence on academic achievement and physics learning outcomes.

Data collection in the present study was conducted using a researcher-made academic achievement test developed based on the content of the first chapter of the tenth-grade physics textbook. The instrument was designed to evaluate students' levels of understanding, application, and problem-solving ability in physics concepts. The test consisted of 12 descriptive and completion-type questions. Questions 1, 6, and 7 assessed students' understanding and comprehension of physics concepts, questions 2, 3, 4, 5, and 8 measured the ability to apply physics concepts in practical and everyday situations, and questions 10, 11, and 12 evaluated students' problem-solving skills in physics.

The validity of the instrument was established through expert judgment and content validation procedures. In order to ensure content validity, the researcher reviewed the theoretical foundations and previous literature related to physics education and then consulted educational specialists, experienced physics teachers, and academic experts. The final version of the instrument was approved by the research supervisor after revisions and expert evaluations. Reliability of the test was determined using the split-half reliability method, and the reliability coefficient was reported as 0.74, indicating acceptable internal consistency for the measurement tool.

In addition to the achievement test, the educational intervention itself constituted an important component of the data collection process. In the experimental group, physics instruction incorporated simple and inexpensive experimental tools, toys, decorative devices demonstrating physical principles, and game-like educational activities to increase students' interest and participation. The instructional activities were designed to connect theoretical concepts with real-world phenomena and encourage active learning and collaborative engagement among students. The control group, however, received instruction using conventional lecture-based methods without the inclusion of phenomenon-based activities or practical demonstrations.

Data analysis was conducted using both descriptive and inferential statistical methods. Descriptive statistics included measures such as frequency, percentage, mean, minimum score, and maximum score in order to summarize the characteristics of the collected data and provide an overview of students' performance in the pre-test and post-test stages.

Before testing the research hypotheses, the assumptions required for inferential statistical analyses were examined. The normality of data distribution was evaluated using the Kolmogorov–Smirnov test. The results indicated that all significance values were greater than 0.05, confirming that the data followed a normal distribution. Homogeneity of variances across groups was examined using Levene's test, and the results supported the assumption of equal variances between the experimental and control groups. In addition, the homogeneity of regression slopes and the linearity relationship between the covariance variable and dependent variables were assessed and confirmed prior to conducting the main analysis.

To test the research hypotheses, analysis of covariance (ANCOVA) was employed. ANCOVA was used to compare the post-test scores of the experimental and control groups while controlling for pre-test differences. This statistical method allowed the researcher to determine the effectiveness of the phenomenon-based learning method on students' academic achievement, conceptual understanding, application of physics concepts, and problem-solving ability. All statistical analyses were conducted at a significance level of 0.05.

Findings and Results

The present study employed a quasi-experimental pre-test–post-test design with an experimental group and a control group to examine the effectiveness of teaching physics using the Phenomenon-Based Learning (PBL) method compared with the traditional teaching method on the academic achievement of tenth-grade high school students. The experimental group received instruction through the phenomenon-based approach using simple experiments, toys, and observable physical phenomena, whereas the control group continued receiving instruction through conventional lecture-based methods. After implementation of the instructional intervention, post-tests were administered to both groups, and the collected data were analyzed using analysis of covariance (ANCOVA).

Prior to hypothesis testing, the assumptions of ANCOVA were evaluated. The normality of data distribution was examined using the Kolmogorov–Smirnov test. The results demonstrated that all significance levels for academic achievement, understanding, application, and problem-solving variables in both pre-test and post-test stages were greater than 0.05, indicating normal data distribution. Furthermore, Levene's test confirmed the homogeneity of variances across the groups for all variables, including academic achievement ($F=1.149$, $p=0.290$), understanding ($F=0.525$, $p=0.469$), application ($F=0.550$, $p=0.463$), and problem solving ($F=0.642$, $p=0.428$). The homogeneity of regression slopes assumption was also satisfied because the interaction between the pre-test covariance variable and the group factor was not statistically significant. In addition, the assumption of linearity between the covariance variables and dependent variables was confirmed, with F values of 4.830 for academic achievement, 3.123 for comprehension, 5.981 for application, and 2.562 for problem solving ($p<0.05$). These findings indicated that the assumptions required for conducting ANCOVA were fully met.

The main hypothesis of the study examined whether there was a significant difference between the effectiveness of the phenomenon-based learning method and the traditional method on students' academic achievement in physics. The findings revealed a statistically significant difference between the two instructional methods in favor of the experimental group. In addition, the first sub-hypothesis investigated differences in students' understanding and comprehension of physics concepts, the second sub-hypothesis examined students' ability to apply physics concepts in everyday life, and the third sub-hypothesis evaluated differences in problem-solving ability between the two groups. The results of all analyses supported the superiority of the PBL approach over the traditional method.

Table 1. Post-Test Analysis of Covariance Results for Research Variables

Variable	Source	Sum of Squares	df	Mean Square	F	Significance Level	Eta Squared
Academic Achievement	Model Accuracy	480.129	2	240.065	12.112	0.001	0.396
Academic Achievement	Group	398.779	1	398.779	20.119	0.001	0.352
Understanding and Comprehension	Model Accuracy	36.619	2	18.309	3.463	0.042	0.118
Understanding and Comprehension	Group	35.622	1	35.622	4.793	0.035	0.115
Application	Model Accuracy	178.470	1	89.235	6.480	0.004	0.259
Application	Group	106.350	1	106.350	7.723	0.009	0.173
Problem Solving	Model Accuracy	15.061	2	7.531	0.408	0.016	0.201
Problem Solving	Group	13.935	1	13.935	8.588	0.006	0.188

As shown in Table 1, the group effect was statistically significant for all research variables. For academic achievement, the obtained F value was 20.119 at a significance level of 0.001, indicating that students taught using the phenomenon-based learning method achieved significantly higher academic performance than students taught through the traditional method. The eta squared value demonstrated that approximately 35% of the variance in academic achievement was explained by the instructional method. Regarding understanding and comprehension, the findings revealed a statistically significant difference between the groups (F=4.793, p=0.035), suggesting that the PBL method enhanced students' conceptual understanding of physics. The eta squared coefficient indicated that approximately 11% of the variance in comprehension was attributable to the teaching method. The results also showed a statistically significant effect of the instructional method on students' ability to apply physics concepts in everyday life (F=7.723, p=0.009). Approximately 17% of the variance in application ability was explained by the teaching approach. In addition, the problem-solving variable demonstrated a significant group effect (F=8.588, p=0.006), indicating that students instructed through the phenomenon-based learning method exhibited higher problem-solving ability than students in the traditional instruction group. The eta squared coefficient showed that approximately 19% of the variance in problem-solving performance was explained by the instructional method. Overall, the ANCOVA results consistently supported the effectiveness of the PBL approach across all dependent variables examined in the study.

Table 2. Adjusted Means of Research Variables in the Post-Test

Variable	Group	Adjusted Mean	Standard Error	Lower Limit	Upper Limit
Academic Achievement	Experimental (PBL)	29.910	0.996	23.892	27.928
Academic Achievement	Control	19.590	0.996	17.572	21.608
Understanding and Comprehension	Experimental (PBL)	6.345	0.610	5.109	7.581
Understanding and Comprehension	Control	4.455	0.610	3.219	5.691
Application	Experimental (PBL)	15.133	0.830	13.451	16.816
Application	Control	11.867	0.830	10.184	13.459
Problem Solving	Experimental (PBL)	4.442	0.285	3.864	5.019
Problem Solving	Control	3.258	0.285	2.681	3.836

The adjusted means presented in Table 2 indicate that students in the experimental group consistently obtained higher post-test scores than students in the control group across all dependent variables. The highest difference between the groups was observed in academic achievement, where the experimental group achieved an adjusted mean score of 29.910 compared with 19.590 in the control group. Similarly, the adjusted mean scores for understanding and comprehension, application of physics concepts, and problem-solving ability were all higher among students who received instruction through the phenomenon-based learning method. These findings demonstrate that the use of practical demonstrations, simple experiments, toys, and real-life physical phenomena significantly enhanced students' learning outcomes and promoted deeper conceptual understanding compared with traditional lecture-based instruction.

Discussion and Conclusion

The present study was conducted to investigate the effectiveness of teaching physics using the Phenomenon-Based Learning (PBL) method compared with the traditional teaching method among tenth-grade high school students. The findings demonstrated that the phenomenon-based learning approach significantly improved students' academic achievement, conceptual understanding, application of physics concepts in everyday life, and problem-solving ability compared with traditional instruction. These findings indicate that integrating practical phenomena, simple experiments, educational toys, and real-world applications into physics instruction can substantially enhance the quality of learning and students' engagement with scientific concepts.

The results related to the main hypothesis showed that students who were taught through the phenomenon-based learning method achieved significantly higher academic achievement scores than students who received traditional instruction. This finding suggests that active participation in learning activities and direct interaction with observable physical phenomena can facilitate deeper understanding and more durable learning. Traditional teaching methods often emphasize memorization of formulas and passive reception of information, whereas the PBL approach creates opportunities for exploration, experimentation, and conceptual reasoning. Such active engagement likely strengthened students' cognitive processing and facilitated meaningful learning experiences. These findings are consistent with the conclusions of Bedemo, who reported that Problem-Based Learning significantly improved students' achievement and attitudes toward physics compared with conventional instructional methods (14). Similarly, the systematic review conducted by Halim emphasized that PBL approaches generally lead to superior educational outcomes in physics because they encourage active learning, inquiry, and higher-order cognitive engagement (6). The findings are also supported by the work of Williams, who emphasized that modern educational environments increasingly require learner-centered strategies capable of integrating practical and interactive experiences into traditional classrooms (3).

Another important finding of the present study was the significant improvement in students' understanding and comprehension of physics concepts in the experimental group. Students who experienced phenomenon-based instruction demonstrated a greater ability to understand abstract concepts and interpret physical principles than students in the control group. One possible explanation for this result is that the use of observable phenomena, practical demonstrations, and interactive classroom activities transformed abstract theoretical content into concrete and understandable experiences. Physics concepts that are typically perceived as difficult and disconnected from real life became more meaningful when students observed them directly through simple experiments and real-world applications. This finding aligns with the perspective proposed by Redish, who argued that meaningful physics learning requires students to connect scientific concepts with personal experiences and observable phenomena rather than merely memorizing formulas and definitions (4). The findings are also compatible with the educational psychology principles proposed by Gheshlaghi, who emphasized that learning becomes more effective when learners actively engage with educational stimuli and construct knowledge through experience (5).

The results regarding the application of physics concepts in everyday life also demonstrated a significant advantage for the phenomenon-based learning approach. Students exposed to the PBL method showed a stronger tendency to apply physics principles to practical situations and real-life experiences. This outcome can be explained by the contextualized nature of phenomenon-based instruction. In this method, educational activities are directly connected to real-world phenomena, enabling students to recognize the practical value of scientific knowledge. When learners understand how physics concepts operate in daily life, they are more likely to retain and apply the learned information in meaningful contexts. These findings are highly consistent with the arguments presented by Azami and Jafari regarding the educational value of play, experimentation, and practical activities in improving learning outcomes and facilitating the transfer of knowledge to real-life situations (7). Similarly, Cano and Lomibao demonstrated that phenomenon-based educational activities significantly enhanced students' reasoning skills, problem-solving ability, and academic achievement because learners were actively involved in interpreting authentic situations and observable events (16).

The present study also found that the phenomenon-based learning method significantly improved students' problem-solving abilities compared with the traditional method. Problem solving is one of the most important competencies in physics education because it reflects students' ability to analyze unfamiliar situations, apply scientific reasoning, and use conceptual knowledge to generate solutions. The superiority of the experimental group in problem-solving performance may be attributed to the inquiry-oriented and exploratory nature of the PBL approach. Through interaction with practical phenomena and collaborative activities, students were encouraged to analyze situations critically, formulate explanations, and test their reasoning processes. These activities likely strengthened students' analytical thinking and cognitive flexibility. The present findings are strongly supported by the meta-analysis conducted by Dewi et al., which concluded that Problem-Based Learning significantly improves students' problem-solving abilities in physics education (9). Similarly, Argaw et al. found that students exposed to PBL instruction demonstrated stronger motivation and more advanced problem-solving skills than students taught through conventional approaches (15).

The findings of the present study are also consistent with research emphasizing the role of interactive and collaborative educational environments in improving higher-order thinking skills. Suharno et al. demonstrated that PBL-based physics modules significantly enhanced students' critical and creative thinking abilities because learners were required to actively participate in knowledge construction and collaborative inquiry (13). Likewise, Dewi and Nisa reported that PBL instruction supported by electronic learning tools improved students' critical thinking and conceptual mastery in physics education (11). These findings collectively indicate that learner-centered and inquiry-based instructional approaches provide educational conditions that facilitate cognitive engagement and promote deeper learning outcomes.

Another explanation for the effectiveness of the phenomenon-based learning approach may be related to increased student motivation and classroom engagement. Traditional lecture-based instruction often creates passive learning environments in which students play limited roles in the educational process. In contrast, the PBL method used in the present study incorporated toys, simple experiments, and game-like activities that likely increased students' curiosity, enjoyment, and willingness to participate. Educational psychology research suggests that intrinsic motivation and emotional engagement significantly influence learning quality and academic performance. Interactive educational experiences can reduce students' anxiety toward difficult subjects such as physics while simultaneously increasing self-confidence and cognitive persistence. These interpretations are supported by Li et al., who demonstrated that playful pedagogical activities produce more effective educational outcomes than traditional methods because they enhance student motivation and engagement (8). Similarly, Karmila et al. emphasized that active and technology-supported learning environments improve scientific literacy and learner participation in physics education (12).

The results of the present study also reflect broader educational trends emphasizing the integration of innovative and traditional instructional approaches. Modern educational systems increasingly advocate for blended and student-centered learning environments capable of addressing diverse learning needs and preparing students for complex real-world challenges. Susanto et al. argued that effective educational systems must integrate active learning approaches with traditional educational structures in order to maximize educational effectiveness in contemporary learning environments (2). In a similar vein, Peña and Galigao emphasized the necessity of balancing traditional and innovative educational approaches in order to enhance learning quality and student performance (1). The findings of the present study provide additional empirical support for these perspectives by demonstrating that innovative phenomenon-based instructional methods can significantly enhance educational outcomes in secondary school physics classrooms.

Overall, the findings of this study suggest that phenomenon-based learning provides a more effective educational framework for physics instruction than traditional lecture-based approaches. By integrating practical experiences, observable phenomena, collaborative inquiry, and active participation into classroom instruction, the PBL method enhances students' academic achievement, conceptual understanding, application of knowledge, and problem-solving abilities. These findings support the growing body of literature advocating for learner-centered and inquiry-based instructional practices in science education and highlight the importance of transforming traditional physics classrooms into more interactive and meaningful learning environments.

One limitation of the present study was the relatively small sample size and the restriction of participants to female tenth-grade high school students from a single educational setting, which may limit the generalizability of the findings to other populations and educational contexts. Another limitation was the relatively short duration of the educational intervention, as longer implementation periods might produce stronger or more stable effects on learning outcomes. In addition, the study relied primarily on a researcher-made academic achievement test, and the inclusion of additional standardized assessment tools or qualitative methods could have provided deeper insights into students' learning experiences and cognitive development.

Future research is recommended to examine the effectiveness of phenomenon-based learning approaches across different educational levels, academic subjects, and demographic groups in order to determine the broader applicability of this instructional method. Researchers may also investigate the long-term effects of PBL on retention of knowledge, motivation, creativity, and scientific literacy. Furthermore, future studies could explore the integration of digital technologies, simulations, virtual laboratories, and blended learning strategies within phenomenon-based instructional frameworks to determine how technological innovations may further enhance students' learning outcomes and classroom engagement.

From a practical perspective, educational policymakers, curriculum developers, and physics teachers are encouraged to incorporate phenomenon-based instructional activities into secondary school science curricula. The use of simple experiments, educational toys, real-world demonstrations, collaborative projects, and inquiry-based classroom activities can create more attractive and meaningful learning environments for students. Teacher training programs should also emphasize active learning methodologies and provide educators with practical strategies for implementing phenomenon-based instruction effectively in classroom settings. In addition, schools should provide sufficient educational resources and laboratory facilities to support the implementation of interactive and experiential learning approaches in physics education.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

All ethical principles were adhered in conducting and writing this article.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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