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EFFORTS TO ENHANCE CRITICAL THINKING SKILLS AND ATTITUDES TOWARD SCIENCE THROUGH THE PROBLEM-BASED LEARNING MODEL

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ABSTRACT

The development of students' critical thinking skills and attitudes toward science is essential for strengthening the quality of education in Indonesia. However, observations at a senior high school revealed that students demonstrated limited critical thinking abilities and low attitudes toward science, particularly in physics learning. This study aimed to describe the implementation of the Problem-Based Learning model and to examine its role in improving students' critical thinking skills and attitudes toward science. The research employed a classroom action research design consisting of two cycles, each involving planning, action, observation, and reflection, in which the teacher systematically plans and implements instructional interventions, observes student responses, and reflects on outcomes to refine subsequent teaching actions. Data were collected through tests of critical thinking skills and questionnaires measuring attitudes toward science. The findings showed substantial improvements in all five indicators of critical thinking, with stronger gains observed in the second cycle following instructional refinements. Students' attitudes toward science also improved across all indicators, including interest, learning activities, perceived importance of science, and interest in pursuing science-related careers. The results indicate that the Problem-Based Learning model contributed to significant improvements in students' engagement, reasoning ability, and positive perceptions of science.

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1. INTRODUCTION

Education plays a significant role in shaping the future of Indonesia. A well-structured and effective educational system will inevitably produce young generations with strong understanding and critical thinking skills, enabling the nation to progress and become more advanced in terms of human resources. Teachers serve as the key to achieving educational goals, as they are the ones who directly implement school programs. Therefore, the instructional processes carried out by teachers must stimulate the development of learners across cognitive, affective, and psychomotor domains (Nafiati, 2021; Ulfah et al., 2021).

In the era of globalization and rapid technological advancement in the 21st century, the skills required to succeed in the professional world and in daily life have changed significantly. The 21st century is characterized by accelerated technological progress, globalization, and dramatic social transformation. The skills needed for success are no longer limited to academic knowledge but also include practical and interpersonal competencies that are increasingly essential. These 21st-century skills are commonly categorized into the 4Cs: critical thinking, creativity, collaboration, and communication (Mustika, 2023).

Critical thinking refers to reflective and in-depth thinking that supports decision-making and problem-solving by enabling individuals to analyze situations, evaluate arguments, and draw sound conclusions (Anggraeni et al., 2022). Critical thinking ability is a cognitive activity involving systematic and detailed analysis of problems. This process includes identifying the core issues, filtering relevant information, and devising strategies to solve them (Fitri, 2020). Critical thinking skills must meet five key indicators: inference, assumption recognition, deduction, interpretation, and evaluation of arguments, in accordance with the WGCTA (Watson & Glaser, 1980).

The reality of students' critical thinking abilities in Indonesia is still far from expectations. The results of the 2022 PISA assessment indicate that the quality of Indonesia's education has declined compared to the 2018 PISA results. Indonesian students' performance in the science domain scored 383 points, showing a decrease from the 2015–2018 cycle. This score also remains below the average of OECD (Organisation for Economic Co-operation and Development) member countries. These findings suggest an urgent need for school learning practices that emphasize higher-order thinking skills to improve the quality of education in Indonesia (Desiriah & Setyarsih, 2021; Esti et al., 2023). Data from Indonesia's PISA and TIMSS results can be interpreted as evidence that the country remains at a low proficiency level, demonstrating that Indonesian students' reading, mathematics, and science literacy are still far from the desired educational outcomes. According to studies by Azrai (2020) and Wulandari & Warni (2022), the consistently low PISA and TIMSS scores imply that students' critical thinking abilities are also low.

After conducting preliminary observations and evaluating suitable research sites, the researcher selected SMAN 1 Kampar Kiri as the location for the study. Based on observations conducted on January 15, 2025, through open interviews with three physics teachers, it was found that physics classes are predominantly scheduled in the afternoon and late afternoon, often causing students to feel tired and less focused. Moreover, the school lacks a physics laboratory, which limits the implementation of physics learning. There are three physics teachers at the school, and one of them does not come from a physics education background, which may affect the quality of instruction delivered. The results of open-ended interviews conducted with two physics teachers indicated that students at SMAN 1 Kampar Kiri tend to have low levels of critical thinking skills. Based on a needs analysis administered to 30 students at SMAN 1 Kampar Kiri, 83.3% of the students reported that physics learning at school had not yet fostered their critical thinking abilities, and 76.7% of respondents stated that physics instruction oriented toward developing critical thinking skills is urgently needed.

Although numerous studies have examined the effectiveness of Problem-Based Learning in improving students' critical thinking skills, most of these studies were conducted in schools with adequate learning facilities and laboratory support. Research investigating the implementation of PBL in resource-limited school environments, particularly in schools without physics laboratories, remains limited (Alfiah & Dwikoranto, 2022; Aprina et al., 2024). This issue is globally significant because many schools in developing countries continue to face infrastructural limitations while simultaneously being required to foster 21st-century skills such as critical thinking (González-Pérez & Ramírez-Montoya, 2022; Roshid & Haider, 2024). Therefore, investigating the implementation of PBL in limited-facility contexts is important to determine whether student-centered learning approaches can still effectively enhance students' critical thinking skills and attitudes toward science despite constrained educational resources.

Students with low critical thinking skills are often affected by several interrelated factors, including the use of one-way teaching methods in which teachers deliver information while students merely listen. Such an approach does not encourage students to think critically or actively engage in the learning process (Gapari, 2025; Kusuma & Nurmawanti, 2023). Students are also frequently not given opportunities to apply their knowledge in real-life contexts. Learning that relies more on memorization and repetition rather than analysis and evaluation hinders the development of critical thinking skills. Critical thinking instruction in schools can be facilitated through various approaches, one of which is the Problem-Based Learning (PBL) model (Aprilia et al., 2024; Darwati & Purana, 2021). The Problem-Based Learning model places students at the center of the learning process by presenting real-world problems as the context for learning (Aprina et al., 2024). Through PBL, students are encouraged to work collaboratively, explore information, ask questions, and seek solutions to the problems presented (Yuniar et al., 2022). This process not only increases student engagement in learning but is also expected to serve as a platform to stimulate students' reasoning and active participation (Darwati & Purana, 2021).

The Problem-Based Learning model is expected to make the physics learning process more engaging for students by providing them with deeper insights that may foster a greater appreciation for the subject (Sutrisna & Sasmita, 2022). This engaging learning process serves as an effort to improve students' attitudes toward science in a more positive direction (Susanti, 2020). Based on the needs analysis, physics is still perceived as a difficult subject to understand, indicating that students' attitudes toward science—particularly in physics—remain negative. Students often perceive physics as a difficult and intimidating subject, which adversely affects the learning process (Piliang et al., 2021; Rahmaddani et al., 2025). This suggests that students still possess low attitudes toward science. If this condition persists, it is likely that learning outcomes in physics will remain low, potentially even lower than in other subject areas.

Students' attitudes toward science can be improved by reshaping their perception of physics as a school subject (Maison et al., 2020). Physics instruction needs to highlight the relevance and importance of physics in students' daily lives through the application of the PBL model, while also helping students recognize that without physics, many technologies used by society today could not have been created or developed. The quality of students' physics achievement is influenced by their attitudes toward science throughout the learning process (Pujiyanti et al., 2021). the objectives of this study are (1) to describe the implementation of the Problem-Based Learning model in improving students' critical thinking skills and attitudes toward science and (2) to describe the outcomes of implementing the Problem-Based Learning model in enhancing students' critical thinking skills and attitudes toward science.

2. METHOD

This study employed a classroom action research (CAR) method based on the model developed by Kemmis and McTaggart (1998) because the objective was not only to examine the effect of Problem-Based Learning on students’ critical thinking skills, but also to improve the learning process within a classroom context characterized by limited educational facilities. Compared to a quasi-experimental design, CAR was considered more appropriate as it allows continuous reflection and improvement through cyclical stages of planning, action, observation, and reflection, while enabling researchers to adapt the learning process to classroom needs and constraints. The success indicator of the learning process is defined by a minimum of 75.00% of students reaching the 'Good' category (Djamarah & Zain, 2006). The research design is presented in Figure 1.

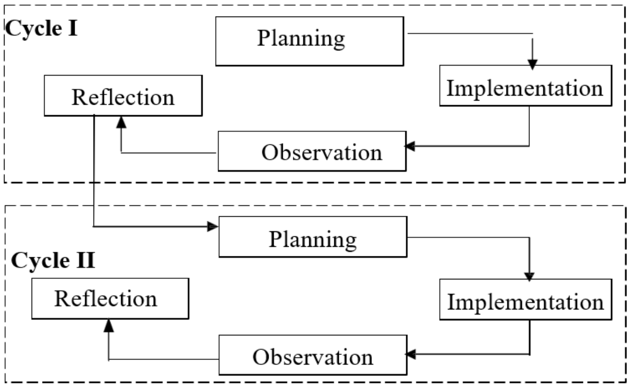

Figure 1. Classroom Action Research Procedure

The research instruments consisted of critical thinking skill tests, an attitudes toward science questionnaire, observation sheets for both teacher and student activities, and learning materials designed based on the PBL model. This study was conducted with 32 students of Class XI.1 at SMAN 1 Kampar Kiri as the research subjects**.** Data were collected through observations, questionnaires, and written tests conducted before and after each learning activity. The collected data were then analyzed using descriptive and quantitative approaches to identify changes in students' learning activities, critical thinking skills, and attitudes toward science.

Each aspect of critical thinking skills was measured using test items that had been aligned with the corresponding indicators and instructional material. The scoring criteria for assessing students’ critical thinking skills are presented in Table 1:

Table 1. Category analysis of critical thinking skills

SN	Percentage	Category
1	$80 \leq X \leq 100$	Excellent
2	$60 \leq X < 80$	Good
3	$40 \leq X < 60$	Fair
4	$0 \leq X < 40$	Poor

The percentage of scores from the Student Attitudes Toward Science questionnaire was analyzed based on the criteria presented in Table 2:

Table 2. Category analysis of attitudes toward science

SN	Percentage	Category
1	$85 \leq X \leq 100$	Excellent
2	$70 \leq X < 85$	Good
3	$55 \leq X < 70$	Fair
4	$40 \leq X < 55$	Poor
5	$0 \leq X < 40$	Very Poor

3. RESULTS AND DISCUSSION

The observation activities supported by pre-cycle data indicated that the critical thinking skills and attitudes toward science of students in Class XI.1 at SMAN 1 Kampar Kiri were at a level that required improvement. The pre-cycle questionnaire results showed that 23 students were categorized as having poor attitudes toward science, 8 students were in the fair category, and 1 student was in the good category. Efforts to enhance students' critical thinking skills and attitudes toward science were carried out through the implementation of an instructional model.

3.1. Students' Sritical Thinking Skills

Critical thinking skills consist of five indicators as previously discussed. The critical thinking skills test comprised 10 items for each cycle, administered at the end of each cycle. The results of students' critical thinking skills in Cycle I and Cycle II are presented in Figure 2.

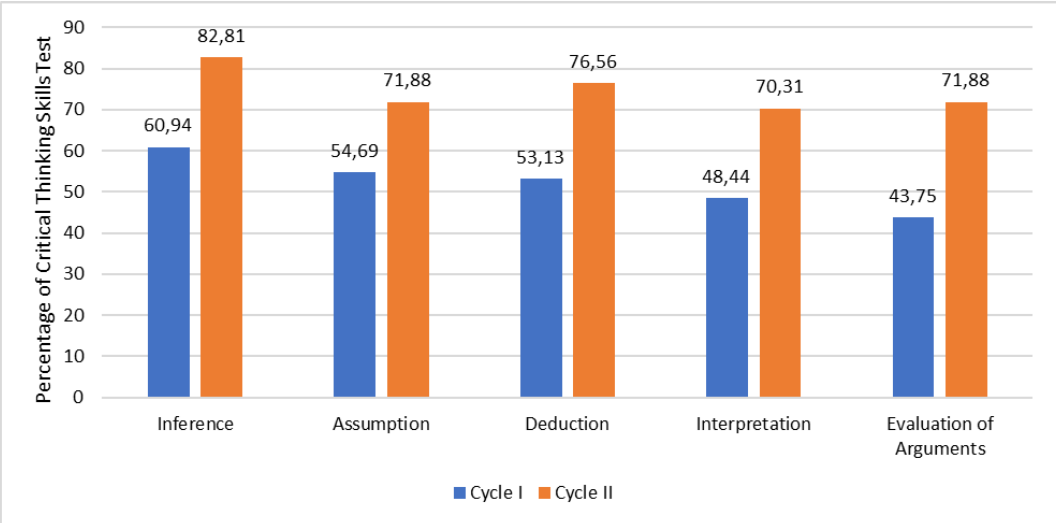

Figure 2. Students' Critical Thinking Skills Test Results

Figure 2 illustrates the improvement in critical thinking skills across each indicator from Cycle I to Cycle II. The improvement across the five WGCTA indicators suggests that the PBL activities not only exposed students to physics problems and activated specific cognitive processes related to critical thinking, while the reflection stage in Cycle I also contributed through follow-up actions in the form of enhanced instructional strategies implemented in Cycle II.

The first indicator, Inference, scored 60.94% in Cycle I (categorized as Good) and increased to 82.81% in Cycle II (categorized as Excellent). This gain is cognitively grounded in the first syntax of PBL, which involves orienting students to the problem, where the teacher introduced a real-world problem through the "*Solve the Case!*" section of the LKPD. Exposure to an authentic, ill-structured problem before receiving formal instruction compels students to draw tentative conclusions from incomplete information, directly exercising inferential reasoning. This instructional condition aligns with Kapur's (2024) concept of *productive failure*, which posits that when learners attempt to construct meaning independently prior to explicit teaching, inferential encoding is significantly deepened. The progressive strengthening of this indicator across two cycles reflects the cumulative effect of repeated inferential practice within each problem orientation stage.

The second indicator, Assumption Recognition, scored 54.69% in Cycle I (categorized as Fair) and increased to 71.88% in Cycle II (categorized as Good). This improvement was related to the third PBL syntax, guiding individual and group investigation, where students were required to write their initial assumptions before conducting experiments. This activity encouraged students to recognize and reflect on their own prior beliefs. According to Chinn et al. (2021), making assumptions explicit is essential for conceptual change because learners need to consciously recognize their beliefs before revising them. When experimental results differed from their initial assumptions, students experienced cognitive conflict that stimulated critical re-evaluation of their ideas. In addition, the fifth syntax, analyzing and evaluating the problem-solving process, further strengthened students' ability to reassess their assumptions through reflective discussions guided by the teacher.

The third indicator, Deduction, scored 53.13% in Cycle I (categorized as Fair) and increased to 76.56% in Cycle II (categorized as Good). This improvement was related to the fourth PBL syntax, developing and presenting results, where students organized experimental data, formulated conclusions, and compared their initial hypotheses with their final solutions. This process reflects hypothesis-evidence coordination, which requires learners to connect observed data with scientific principles and determine whether the evidence supports a conclusion (Saleh et al., 2022). When discrepancies emerged between experimental findings and theoretical predictions, students engaged in deductive reasoning to resolve the inconsistency. Group presentations also strengthened deductive thinking because students were required to justify their conclusions based on the evidence obtained.

The fourth indicator, Interpretation, scored 48.44% in Cycle I (categorized as Fair) and increased to 70.31% in Cycle II (categorized as Good). During the third and fourth PBL syntaxes, students searched for relevant data, recorded findings, and analyzed experimental results. These activities developed students' ability to connect evidence with scientific understanding and construct justified interpretations. According to Lee et al. (2024), this process reflects epistemic knowledge associated with scientific experimentation, which develops through activities involving data collection, measurement, and interpretation. The LKPD scaffolding guided students from simple data recording toward evidence-based interpretation, while the final task requiring students to formulate solutions based on experimental findings further strengthened their interpretative reasoning skills.

The fifth indicator, Evaluation of Arguments, scored 43.75% in Cycle I (categorized as Fair) and increased to 71.88% in Cycle II (categorized as Good). This indicator showed the lowest initial score, which is consistent with studies suggesting that argument evaluation is one of the most cognitively demanding higher-order thinking skills (Guilfoyle & Erduran, 2021). The improvement was mainly influenced by the fifth PBL syntax, analyzing and evaluating the problem-solving process, where students reflected on the relationship between their initial hypotheses and final experimental results. This activity encouraged metacognitive monitoring, which plays an important role in evaluative thinking in science learning (Fono & Zohar, 2025). In addition, the presentation stage created opportunities for students to assess both their own arguments and those of their peers, which further strengthened their evidence-based evaluative reasoning (Park et al., 2022).

Overall, there was a consistent and significant improvement across all indicators of students' critical thinking skills following the implementation of the problem-based learning model integrated with LKPD. This improvement was evident across the five WGCTA critical thinking indicators: inference, assumption, deduction, interpretation, and evaluation of arguments. Students' critical thinking skills developed optimally during Cycle I and strengthened further in Cycle II. This finding aligns with Sasmita (2021) and Ananda (2022), who assert that the problem-based learning model is effective in enhancing students' critical thinking skills because it emphasizes authentic problem-solving, data analysis, and the construction of evidence-based arguments.

3.2. Students' Attitudes Toward Science

The results of students' attitudes toward science were obtained from the questionnaire that had been administered. The questionnaire consisted of 24 statements covering four indicators of attitudes toward science. Based on the findings, there was an improvement in students' attitudes toward science from the pre-cycle to Cycle I and subsequently to Cycle II. The results of the students' attitudes toward science questionnaire are presented in Figure 3.

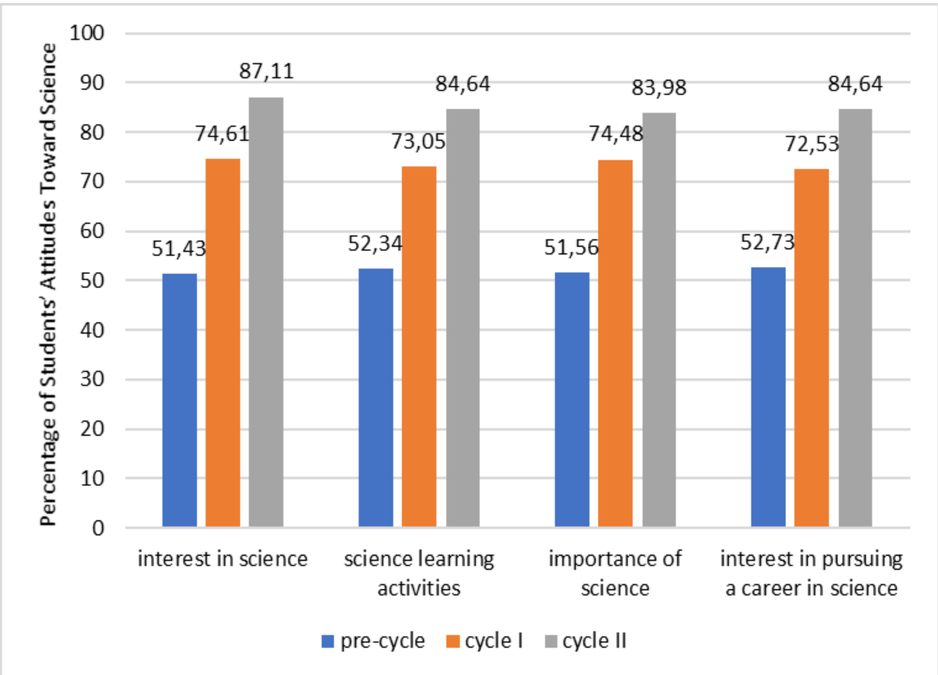

Figure 3. Students' Attitudes Toward Science Questionnaire Results

Based on Figure 3 presented in the research findings, it was determined that students' attitudes toward science during the teaching and learning process using the problem-based learning model had improved. Each indicator of students' attitudes toward science showed an increase.

The indicator "*Interest in Science*" increased from 51.43% (pre-cycle, categorized as Fair) to 74.61% (Cycle I, categorized as Good), and further increased to 87.11% (Cycle II, categorized as Excellent). This improvement can be explained through situational interest theory, which states that students' interest is influenced by the learning environment, particularly the relevance and novelty of learning activities. In the pre-cycle, students had limited awareness of the connection between scientific concepts and daily life. The "Solve the Case!" stage in PBL addressed this issue by presenting authentic real-world problems as the starting point of learning. When students recognized the practical value of scientific knowledge in solving everyday problems, their engagement with science increased significantly. Li et al. (2024) explain that PBL environments encourage authentic inquiry and sustained engagement with scientific practices, which can strengthen students' long-term interest in science. The continuous increase across two cycles indicates that repeated exposure to contextual problem-solving activities gradually developed students' interest in science.

The indicator "*Science Learning Activities*" increased from 52.34% (pre-cycle, categorized as Fair) to 73.05% (Cycle I, categorized as Good) and 84.64% (Cycle II, categorized as Good). This improvement reflects a shift from passive to active engagement during learning. Through PBL, students actively collected data, formed hypotheses, conducted experiments, and collaborated to solve problems. Wang et al. (2024) explain that learning environments supporting autonomy, competence, and collaboration can enhance students' intrinsic motivation and active engagement in learning. Bureau et al. (2021) also confirm through meta-analysis that fulfilling these learning needs contributes to stronger student engagement and persistence in academic activities. These conditions contributed to the significant increase in students' active participation in science learning across both cycles.

The indicator "*Importance of Science*" increased from 51.56% (pre-cycle, categorized as Fair) to 74.48% (Cycle I, categorized as Good), and further increased to 83.98% in Cycle II (categorized as Good). In the pre-cycle, students tended to perceive science as abstract and disconnected from everyday life. Through PBL, students applied scientific concepts to authentic and relevant problems, making the practical value of science more visible and meaningful. Schoenherr et al. (2024) explain that students' motivation and engagement increase when learning activities are connected to real-world goals and applications. By experiencing how scientific knowledge can be used to solve real problems, students developed a stronger perception of the importance of science across both cycles.

The indicator "Interest in Pursuing a Career in Science" increased from 52.73% (pre-cycle, categorized as Fair) to 72.53% (Cycle I, categorized as Good), and further increased to 84.64% (Cycle II, categorized as Good). In the pre-cycle, students had limited understanding of science-related careers because learning was disconnected from real-world scientific practice. Through PBL, students engaged in authentic tasks such as designing water irrigation systems and dam structures, which reflected the work of scientists and engineers. Fong et al. (2021) explain that students are more motivated to pursue science careers when learning activities are perceived as relevant to their future goals. In addition, Mims et al. (2025) found that authentic hands-on science activities can strengthen students’ science identity and interest in science-related careers. As students successfully solved real-world problems throughout both cycles, their confidence and interest in pursuing careers in science gradually increased.

Based on the questionnaire data presented in the research findings, it was determined that students’ attitudes toward science after participating in the teaching and learning process using the problem-based learning model had improved and met the success criterion, namely that the percentage of students categorized as *Good* and *Excellent* reached ≥ 75.00%. The questionnaire results clearly show an increase in students’ attitudes toward science following the implementation of the problem-based learning model. This is consistent with the findings of Kanyesigye et al. (2022), which report that the problem-based learning model is effective in enhancing students’ attitudes toward science.

4. CONCLUSION

This study investigated the implementation of the Problem-Based Learning (PBL) model in physics learning at the senior high school level and its effectiveness in improving students' critical thinking skills and attitudes toward science. The findings demonstrate that PBL implementation across two classroom action research cycles produced consistent and significant improvements in both cognitive and affective dimensions of science learning. Regarding critical thinking skills, all five WGCTA indicators, namely inference, assumption recognition, deduction, interpretation, and evaluation of arguments, showed progressive improvement from Cycle I to Cycle II. The lowest-scoring indicator in Cycle I, evaluation of arguments (43.75%), reached 71.88% in Cycle II, while the highest-scoring indicator, inference, advanced from 60.94% to 82.81% and reached the Excellent category. These gains were driven by specific cognitive mechanisms embedded within each PBL syntax: the "Solve the Case!" problem orientation stage activated inferential and assumption-recognition processes; the investigation stage fostered deductive and interpretive reasoning through hypothesis-evidence coordination; and the structured reflection and peer evaluation stage cultivated evaluative thinking through metacognitive engagement. Regarding attitudes toward science, all four indicators, namely interest in science, science learning activities, importance of science, and interest in pursuing a career in science, improved substantially across cycles and met the established success criterion of 75.00% or more students categorized as Good or Excellent by Cycle II. These improvements reflect a shift in students' motivational orientations, from passive recipients of information toward active, engaged learners who recognized the practical relevance of science in everyday life and future careers. The PBL model fulfilled students' basic psychological needs for autonomy, competence, and relatedness, which collectively strengthened intrinsic motivation and positive science attitudes. These findings contribute to the growing body of evidence that PBL is an effective instructional model for simultaneously developing cognitive and affective outcomes in secondary science education. The study demonstrates that the effectiveness of PBL lies not in its general structure alone, but in the quality of cognitive activation at each instructional phase and the authenticity of problem contexts presented to students. Practically, this research implies that physics teachers can strategically implement PBL with contextual, real-world problem design and structured LKPD scaffolding to meaningfully improve both critical thinking skills and science attitudes among high school students. Future research is encouraged to examine the long-term retention of these gains and to explore the implementation of PBL across diverse physics topics and broader student populations.

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