



Problem-Based Learning: A Catalyst for the Development of Students' Critical Thinking and Science Process Skills

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ABSTRACT

This study investigates the implementation of a problem-based learning (PBL) model to enhance students' critical thinking and science process skills in science courses. The research was conducted within the Islamic Elementary School Teacher Education Study Program, Faculty of Islamic Studies, University of Islam Malang. A qualitative approach was employed, utilizing interviews, observations, and documentation techniques for data collection. Data were analyzed through an interactive analysis model following the framework proposed by Miles, Huberman, and Saldana, consisting of three stages: data condensation, data display, and conclusion drawing/verification. The findings indicate that the Natural Science course was conducted through the application of the PBL model, which involved several key stages: (a) orienting students to the problem, (b) organizing students for learning, (c) guiding investigations, (d) developing and presenting solutions, and (e) analyzing and evaluating the problem-solving process. The application of the PBL model was found to significantly improve students' critical thinking and science process skills. The results of this study are expected to provide valuable insights for lecturers and educational institutions in designing learning strategies that foster the development of students' higher-order thinking and scientific inquiry skills. Further research is recommended to examine the long-term effects of the PBL model on students' skill development and their preparedness for teaching practice.

Keywords: *natural science, critical thinking, science process skills, problem-based learning.*

INTRODUCTION

Natural Science is a fundamental course that discusses the basic concepts of physics, chemistry, biology, and the environment. It is designed to provide students with a comprehensive understanding of scientific principles that underlie everyday phenomena and their applications in various aspects of human life (Cahyanto, Srihayuningsih, et al., 2024). As a compulsory subject for students in the Islamic Elementary School Teacher Education Study Program, Faculty of Islamic Studies, University of Islam Malang, this course aims to equip future educators with scientific knowledge that can be integrated into elementary-level instruction (Baharom et al., 2020; Gizaw & Sota, 2023). Through this course, students are expected to develop critical and analytical thinking skills, enabling them to teach scientific concepts effectively. Moreover, it is intended to cultivate an awareness of the relevance of science in daily life and to nurture a scientific attitude aligned with Islamic values, thereby producing educators who are both academically competent and morally grounded (Celik, 2022; Mushani, 2021).

The Natural Science course has been structured to ensure both theoretical mastery and practical competence in teaching science at the elementary school level. In this course, students are introduced to foundational scientific concepts in physics, chemistry, and biology, which serve as the basis for science education in schools. In addition to theoretical understanding, students are trained to implement experiment-based learning, investigative methods, and problem-based approaches that enhance critical and analytical thinking (Seibert, 2021; Thorndahl & Stentoft, 2020). Emphasis is also placed on the use of innovative instructional models and strategies to deliver scientific content in engaging and effective ways. Direct experiences are provided through activities such as designing simple experiments, observing natural phenomena, and developing age-appropriate teaching strategies for elementary learners. These experiences are expected to strengthen students' ability to become adaptive and competent educators who can foster curiosity and a lasting interest in science (Amin et al., 2020; Miller et al., 2023).

In the context of 21st-century education, critical thinking has been recognized as an essential skill that every individual, particularly future educators, must possess. To navigate the complexity of modern challenges, students must be capable of analyzing, evaluating, and solving problems systematically (Gholami et al., 2016; Ma et al., 2023; Tang et al., 2020). Consequently, higher education, especially science-related courses, must be designed to strengthen students' critical thinking abilities (Banegas et al., 2024; Darwin et al., 2024). One pedagogical approach considered effective in this regard is the Problem-Based Learning (PBL) model, which encourages students to independently explore scientific concepts, identify solutions to real-world problems, and engage in reflective thinking processes (Ardiansya et al., 2024; Vossos et al., 2023). Furthermore, students in Islamic Elementary School Teacher Education Study Program must also develop science process skills—skills that enable them to apply scientific methods in understanding, constructing, and discovering knowledge (Astalini et al., 2023; Rini & Aldila, 2023).

Science process skills encompass various cognitive and procedural abilities such as observing, measuring, classifying, inferring, predicting, and communicating (Apaivatin et al., 2021; Cetin & Ozdemir, 2018). Mastery of these skills allows future teachers to go beyond theoretical instruction and to promote active learning in which elementary students can observe, experiment, and discover scientific principles independently (Darmaji et al., 2020; Gunawan et al., 2019). However, previous studies have identified persistent gaps in higher education practices regarding the integration of strategies that simultaneously enhance critical thinking and science process skills (Darwin et al., 2024). Research has indicated that instructional approaches in science courses often remain conventional, thereby limiting opportunities for inquiry and independent exploration (Yuliskurniawati et al., 2019; Setiawan & Sugiyanto, 2020). Consequently, further investigation is needed to determine how the PBL model can be effectively utilized to strengthen these competencies, ensuring that students are better prepared to become professional educators.

This necessity aligns with the demands of 21st-century education, which emphasizes higher-order thinking skills (HOTS) and scientific literacy through learning approaches that integrate conceptual understanding with real-world application (Indri et al., 2020; Mohammed et al., 2020). Prospective teachers, in particular, are required not only to master subject matter but also to cultivate curiosity, encourage inquiry, and foster scientific reasoning among their students from an early age. Elementary students, by nature, learn best through observation, experimentation, and hands-on experiences rather than through passive instruction (Suryawati & Osman, 2017; Widyaningsih et al., 2020). Therefore, science teachers must be capable of designing interactive and investigation-based lessons that connect scientific concepts to students' everyday experiences.

To meet these expectations, students in the Islamic Elementary School Teacher Education Study Program must be systematically trained to design innovative, experiment-oriented lessons that strengthen science process skills (Yuliskurniawati et al., 2019; Restiana & Djukri, 2021). The PBL model is particularly relevant for this purpose, as it promotes critical thinking, problem-solving, and the application of scientific methods in authentic contexts (Akçay & Benek, 2024;

Ramanathan et al., 2025). Nonetheless, challenges persist in the implementation of science instruction in schools, where traditional, teacher-centered approaches are still prevalent (Ainun & Maryati, 2024; Rahmah et al., 2023). Such practices often reduce student engagement and hinder deep conceptual understanding. Therefore, pre-service teachers must be optimally prepared to design and implement inquiry-based science lessons that enable students to observe phenomena, collect data, and draw conclusions through guided experimentation.

At the University of Islam Malang, the Islamic Elementary School Teacher Education Study Program under the Faculty of Islamic Studies has begun to integrate innovative learning models emphasizing exploration, investigation, and concept discovery through experiential learning. These approaches are intended to shift students from passive recipients of information to active participants in observation, analysis, and evidence-based reasoning. Against this background, the present study was conducted to examine in depth the implementation of the Problem-Based Learning model in the Natural Science course and its impact on enhancing students' critical thinking and science process skills. The findings are expected to provide empirical insights into the effectiveness of the PBL approach in science education and to contribute to the development of pedagogical strategies that prepare competent, innovative, and reflective educators capable of nurturing scientific understanding among future generations.

METHODOLOGY

The methodological framework of this study was carefully designed to ensure rigor, credibility, and methodological coherence. This section provides a detailed explanation of the research design, participant characteristics, data collection and analysis procedures, as well as the strategies employed to maintain validity and ethical integrity throughout the research process.

Research Design

A qualitative case study design was employed to obtain a comprehensive and in-depth understanding of the implementation of the Problem-Based Learning (PBL) model and its influence on the development of students' critical thinking and science process skills within the Natural Science course. This approach was selected because it allows for an exploration of participants' experiences, perceptions, and perspectives particularly those of lecturers and students directly involved in the instructional process (Denzin & Lincoln, 2018; Yin, 2016). Through this design, the study sought to interpret how the PBL model functions as a pedagogical practice within its authentic educational context, thereby enabling a holistic analysis of the observed phenomenon (Creswell, 2018; Frost, 2011). The research was conducted in the Islamic Elementary Teacher Education Study Program, Faculty of Islamic Studies, Universitas Islam Malang. The qualitative case study approach was considered suitable for examining how lecturers plan and deliver PBL-oriented instruction, how students engage in collaborative problem-solving, and how their critical thinking and scientific inquiry skills develop over time. By situating the investigation within an actual classroom environment, the study was able to capture the complex interplay among pedagogical practice, cognitive development, and student engagement in a natural educational setting.

Participants

The participants consisted of one course lecturer and eight students enrolled in the Natural Science course during the second semester of the 2022/2023 academic year. A purposive sampling technique was applied Neuman (2014) to ensure that the participants possessed direct experience and involvement in the implementation of the PBL model. The selected lecturer had substantial teaching experience and consistently integrated PBL strategies into instructional design. The

students were active course participants who were able to provide authentic reflections on their learning experiences. Participant selection also considered gender representation and the level of classroom engagement to ensure diversity and data richness. Prior to data collection, all participants were fully informed about the objectives, procedures, and potential implications of the study. Informed consent was voluntarily provided, and confidentiality was ensured through the assignment of pseudonyms and unique identification codes during the analysis and reporting processes. Ethical considerations were strictly maintained in accordance with institutional guidelines and research ethics standards.

Data Collection and Analysis

Data were collected through three primary techniques: interviews, classroom observations, and document analysis. The use of multiple data sources allowed for methodological triangulation, which enhanced the credibility and validity of the findings. Semi-structured interviews were conducted to gain an in-depth understanding of participants' experiences and perspectives regarding the implementation of the PBL model. A total of nine interview sessions were held one with the lecturer and eight with individual students each lasting approximately 30 to 45 minutes. The interview protocol was structured around three major themes: instructional planning, implementation of PBL activities, and the perceived impact of the PBL approach on students' critical thinking and science process skills. All interviews were audio-recorded and transcribed verbatim to maintain the authenticity and integrity of the data. To complement the interview data, non-participant classroom observations were conducted to document real-time interactions, instructional practices, and student engagement during PBL sessions. Field notes were used to record contextual information, providing additional insights that helped verify the consistency between reported experiences and actual classroom practices.

In addition, document analysis was performed to examine relevant instructional materials, including lesson plans, student worksheets, and reflective journals. These documents served to corroborate evidence obtained from interviews and observations. The entire data collection process was iterative and reflective, allowing continuous refinement of emerging patterns and themes. Data analysis was conducted using the interactive model proposed by Miles, Huberman, and Saldana (2014), which consists of three interconnected stages: data condensation, data display, and conclusion drawing/verification. During the condensation phase, relevant information was identified, coded, and categorized to highlight patterns related to the implementation of PBL and its observed effects. In the display phase, the data were organized into thematic matrices to facilitate interpretation. The final phase involved drawing conclusions and verifying findings by cross-referencing evidence from multiple sources to ensure consistency and validity. A summary of the interview guide used in this study is presented in Table 1, which outlines the key questions corresponding to the major themes explored during data collection.

Table 1. Research Interview Guide

Research Focus	Sub focus	Description	Instrument Grid
Implementation of Problem-Based Learning Model	Learning Planning	Exploring understanding and initial preparation in implementing PBL	1. Lecturer understanding of the basic concepts and principles of PBL. 2. Planning relevant and contextual topics or problems. 3. Planning the flow and stages of PBL 4. Preparation of supporting media/learning resources 5. Stages taken in designing learning planning documents
	Implementation of Problem-Based Learning Model	Revealing the implementation of PBL steps	1. Stages passed in learning 2. Group discussion process and teamwork.

Research Focus	Sub focus	Description	Instrument Grid
			- Active role of students in finding and solving problems. - Support and facilitation provided by lecturers during the process. - Obstacles or challenges during the implementation of PBL.
	Assessment and Reflection on Learning	Revealing the process of assessment and reflection in learning	- Lecturer strategies in conducting learning assessments - Assessment methods and techniques used - Student involvement in the assessment process - Constraints in assessment practices carried out by lecturers - Learning reflection process by students and lecturers
The Impact of Implementing the Problem-Based Learning Model	Understanding the Material	Exploring the impact on students' understanding of the material	- Deep understanding of concepts - Linking theory to practice - Ability to identify the core of a problem - Improved understanding of complex concepts - Ability to organize information and construct logical answers
	Relevant skills development	Exploring the impact on student skills	- Behavioral changes that arise from the application of the problem-based learning model - Student perceptions of learning - The process of developing student skills in learning - Dominant skills that emerge during learning - The real impact of the application of the problem-based learning model

In addition to the interviews, non-participant observations were carried out over four instructional sessions. These observations were directed toward several key dimensions, including student interactions, the dynamics of group discussions, the utilization of learning media, and the instructional strategies employed by the lecturer to facilitate scientific inquiry. A structured observation protocol was used to systematically record behaviors, activities, and classroom events that were relevant to the focus of the study. Complementing the observational data, a document analysis was also conducted, which involved the examination of several instructional materials such as lesson plans, student worksheets, laboratory or experiment reports, and students' reflective journals. The integration of these multiple sources of evidence contributed to methodological triangulation, thereby strengthening the credibility, reliability, and depth of interpretation. This triangulated approach ensured that the emergent themes were both empirically substantiated and contextually grounded within the authentic learning environment.

Data analysis was performed using a thematic approach adapted from Yin's (2018) analytic framework, encompassing techniques such as pattern matching, explanation building, time-series analysis, and logic modeling. Throughout the analytical process, both inductive and deductive reasoning were employed to allow theoretical constructs to emerge from the data while remaining responsive to contextual nuances (Auerbach & Silverstein, 2003). The validity of the findings was further reinforced through the use of source triangulation, methodological triangulation, and member checking, which collectively ensured that the interpretations accurately reflected participants' lived experiences and perspectives.

Trustworthiness

To ensure the rigor and reliability of the research findings, four criteria of trustworthiness credibility, transferability, dependability, and confirmability were applied in accordance with the framework proposed by Lincoln and Guba (1985). Credibility was ensured through member checking with key participants, allowing them to verify the accuracy and authenticity of the researcher's interpretations and reported experiences. In addition, peer debriefing sessions were conducted with two subject-matter experts to review the analytical logic, consistency, and coherence of the emerging themes across multiple data sources. Transferability was addressed by providing a rich, detailed description of the research context, participant characteristics, and instructional dynamics observed throughout the study. Such comprehensive documentation enables readers and future researchers to evaluate the applicability and relevance of the findings in comparable educational settings. To establish dependability, all stages of the research were meticulously recorded through a complete audit trail comprising field notes, interview transcripts, coding records, and analytical memos. This systematic documentation facilitated external review and replication of the research process. Confirmability was achieved by maintaining an auditable record of analytical decisions and by applying triangulation across both data sources and research methods. These measures minimized potential researcher bias and reinforced the objectivity and integrity of the interpretations.

Ethical Considerations

This study was conducted in strict adherence to established research ethics protocols. Prior to data collection, formal approval was obtained from the Faculty of Islamic Studies, Universitas Islam Malang. All participants provided informed consent after receiving a comprehensive explanation of the study's objectives, procedures, potential benefits, and foreseeable risks. Participation was entirely voluntary, and participants were informed of their right to withdraw from the study at any time without any academic or social consequences. To ensure confidentiality and data protection, all personal identifiers were anonymized using coded labels, and all digital data were securely stored in encrypted files accessible only to the researcher. The collected data were used exclusively for scholarly and non-commercial purposes. By upholding these ethical principles, the study was conducted with professionalism, transparency, and full respect for participants' dignity, autonomy, and rights.

RESULT AND DISCUSSION

In this section, the research findings are systematically presented in accordance with the main focus and objectives of the study. The results are organized into several thematic subsections that emerged throughout the data collection and analysis process. Each theme reflects a significant aspect of the implementation of the Problem-Based Learning (PBL) model within the Natural Science course of the Islamic Elementary School Teacher Education Study Program, Faculty of Islamic Studies, Universitas Islam Malang. Through this structure, a comprehensive and in-depth depiction of the PBL implementation process and its influence on student learning is provided.

Implementation of the Problem-Based Learning Model

Orienting Students to Problems

The first phase of the Problem-Based Learning (PBL) model involves orienting students to the problem (Ssemugenyi, 2023; Sutarto et al., 2022). In this study, the Natural Science learning process was initiated through the presentation of environmental phenomena serving as real-world stimuli and objects of scientific inquiry. These phenomena were delivered using PowerPoint media and functioned as triggers for classroom discussion. The selected phenomena were deliberately

contextualized to students' daily lives, enabling them to establish direct connections between the discussed topics and real experiences while simultaneously stimulating curiosity about scientific issues (Ramdani et al., 2023; Safitri et al., 2023).

Following the presentation of the stimulus, the lecturer posed a series of provocative and inquiry-based questions designed to encourage critical reflection and analytical reasoning (Banegas et al., 2024; Essien et al., 2024). Such questions not only stimulated students' curiosity but also guided them toward identifying, interpreting, and predicting scientific concepts embedded in the observed phenomena. Through this process, students began to formulate problem statements and relate them to the theoretical content of the course. Students were further encouraged to associate the discussed concepts with their own personal experiences. This pedagogical approach was intended to bridge theoretical understanding and practical application (Barrows, 1986; Permata et al., 2022), allowing students to recognize that the acquired knowledge holds significance beyond academic contexts and is applicable to real-life situations, particularly in their future roles as elementary school science educators.

As one participant expressed *"... in learning natural science, students must be able to see the phenomena around them comprehensively because the study of science essentially discusses phenomena in everyday life. As prospective teachers, an understanding of science will help them in conveying material to students later when teaching in a more contextual and applicable way"*. (Interview. LCT.001)

After the orientation stage, students were provided with reading materials containing conceptual explanations relevant to the topic. The lecturer embedded stimulating questions within these materials to promote higher-order thinking and reflective engagement (Ahern et al., 2019; Lorencová et al., 2019). These questions served as scaffolds for students to deepen their comprehension and sustain intellectual curiosity. As a result, learning activities shifted from a teacher-centered approach toward a student-centered model, fostering active participation and idea exploration through discussion and inquiry. This process was found to play a crucial role in creating meaningful learning, as students were not merely passive recipients of information but were actively involved in exploring, constructing, and understanding knowledge (Clarís & Riley, 2012; Puig et al., 2019). Consequently, students demonstrated enhanced critical thinking and a higher degree of learning motivation.

At this stage, the lecturer also provided explicit guidance regarding the central problems to be investigated. The questions were carefully designed to stimulate curiosity and direct students toward scientific exploration (Ainun & Maryati, 2024; Gao et al., 2022). Students actively engaged by observing attentively, taking notes, and expressing their opinions related to the issues being introduced.

As highlighted by the lecturer *"... so far in classroom learning, it has shown that the critical thinking process has begun to grow where students do not only receive information passively, but they learn to relate existing problems to initial knowledge, experience, and concepts that they have learned previously through question and answer discussions in class"*. (Interview. LCT.002)".

Observation results also confirmed that students appeared attentive and enthusiastic during the presentation of problems, indicating that the stimulus effectively captured their curiosity. Moreover, two-way communication was established between lecturers and students, reflected through questioning, responding, and discussion exchanges. This early engagement served as a foundation for students to develop investigation strategies in subsequent stages of the PBL cycle (Alt & Raichel, 2022; Islamiati et al., 2024). Overall, the problem orientation phase in the Natural Science course functioned not only as an introduction to the topic but also as a catalyst for stimulating critical thinking and fostering intrinsic motivation to learn.

Organizing Students to Learn

Following the introduction of the central problem, the subsequent stage in implementing the Problem-Based Learning (PBL) model involves organizing students to learn. This phase plays a pivotal role as it marks the beginning of students' active engagement in collaborative and inquiry-oriented learning (Susilawati & Doyan, 2023; Suwono et al., 2023). During this process, systematic and structured guidance was provided by the lecturer to assist students in developing effective learning strategies tailored to the identified problems. One of the primary strategies applied in this stage was the formation of heterogeneous study groups. The diverse composition of each group was intentionally designed to foster the exchange of perspectives, experiences, and approaches, thereby stimulating students' critical thinking through constructive peer interaction. This collaborative environment was essential, as the resolution of complex problems was viewed not as an individual endeavor, but as a collective process that relies on active participation and the integration of multiple viewpoints (Coumans & Wark, 2024; Wang, 2021).

Once the groups were established, students were encouraged to share their initial understanding of the presented problem. This activity served to elicit prior knowledge and form a foundation for deeper exploration. Through this preliminary discussion, knowledge gaps were identified areas where further investigation and clarification were required (Dewi et al., 2023; Fitriani et al., 2022). Students exchanged experiences, insights derived from prior readings, and observations relevant to the issue under study. The lecturer facilitated this process by helping students structure learning tasks and design a plan of action that included determining the type of information to be sought, identifying relevant learning resources, and organizing the sequence of inquiry. At this point, students were guided to design systematic strategies for addressing the problem. They formulated steps for investigation, identified the data required, selected appropriate resources, and determined the most effective approaches for problem-solving (Chin & Chia, 2004; Fathur Rohman, 2022).

As one of the participants explained, “... *at this stage, after the lecturer explained the problem scenario, we immediately divided into small groups and prepared a work plan in the group. For example, I was assigned to look for scientific journals, while other friends looked for data from textbooks. We all divided the tasks according to our respective expertise*”. (Interview. STD.001)

This statement illustrates that students were able to develop structured problem-solving strategies, including the division of roles and the independent determination of learning resources (Akçay & Benek, 2024; Irwandi et al., 2024). The lecturer further supported this process by encouraging the use of digital technologies to expand students' access to information and to facilitate the analysis of potential solutions.

Each group member was assigned a specific role such as information seeker, data analyst, report compiler, or presenter of discussion outcomes. This task distribution ensured that the learning process proceeded efficiently and that every participant contributed meaningfully to the collective inquiry (Lubis et al., 2022). Through this structured organization of learning activities, students not only deepened their conceptual understanding of Natural Science but also strengthened essential 21st-century competencies including critical thinking, collaboration, communication, and problem-solving skills. These competencies are indispensable for both academic success and professional readiness, particularly in the context of science education and future teaching practice.

Guiding Students in Investigation

After students had successfully organized their learning tasks, the subsequent stage in the implementation of the Problem-Based Learning (PBL) model involved guiding students in conducting investigations. This phase constituted the core of the PBL process, as students were actively engaged in exploring and constructing solutions through systematic inquiry and critical

analysis (Ardiansya et al., 2024; Ssemugenyi, 2023). At this stage, students were encouraged to collect and synthesize information from multiple sources, including textbooks, peer-reviewed journal articles, credible online publications, and previous research studies. Access to a diverse range of learning resources enabled students to develop a more comprehensive and multidimensional understanding of the issues under investigation. The lecturer's role in this phase shifted from being the primary source of information to serving as a facilitator who provided scaffolding, posed probing questions, and guided students in evaluating the validity, reliability, and relevance of the information gathered. Through this facilitative approach, students were trained not only to acquire factual knowledge but also to engage in the cognitive processes of a critical researcher analyzing, interpreting, and reflecting on evidence in light of the presented problems.

In addition to literature exploration, students were also engaged in hands-on scientific experiments as part of their investigative process, particularly in the Natural Science course where empirical inquiry forms the foundation of conceptual understanding (Darwin et al., 2024; Setiawan & Sugiyanto, 2020). Simple laboratory experiments were designed to enable students to test hypotheses, verify theoretical assumptions, and observe scientific phenomena directly. During these activities, systematic observations were made, data were recorded, and analyses were conducted to construct deeper conceptual insights. The lecturer played a vital role in ensuring that the procedures adhered to scientific principles while simultaneously encouraging students to consider methodological rigor and external variables that might influence experimental outcomes (Suryawati & Osman, 2017).

As highlighted by one of the lecturers “... through this activity, students not only develop conceptual knowledge, but also practice scientific skills such as observation, analysis, reasoning, and data-based decision making. This stage strengthens the essence of PBL as an approach that emphasizes the active involvement and personal responsibility of students in building their own knowledge through direct experience”. (Interview. LCT.003)

Upon completing the experimental activities, the data obtained were analyzed collaboratively by students within their respective groups. When discrepancies emerged between experimental results and theoretical expectations, students were encouraged to engage in reflective analysis to identify possible causes, including methodological errors, environmental factors, or limitations in data collection. Such reflective practices were intended to strengthen their metacognitive awareness and ability to evaluate scientific evidence critically. Following data interpretation, students participated in group discussions to examine the patterns or relationships identified in the experimental data, evaluate the consistency between theoretical concepts and empirical results, and formulate viable solutions to the problem under investigation (Susilawati & Doyan, 2023). During these discussions, students demonstrated their capacity to present data-driven arguments and articulate reasoning grounded in evidence.

The lecturer maintained an active but non-directive presence, providing guidance to ensure that discussions remained aligned with the learning objectives and the principles of scientific reasoning. At the conclusion of this phase, each group compiled a comprehensive report containing their findings, analyses, and recommendations for problem resolution. Through this investigative stage, students were able to deepen their conceptual mastery while simultaneously developing essential analytical, reflective, and problem-solving skills, competencies that are critical for both academic advancement and future professional practice in science education.

Developing and Presenting Work Results

After students had completed the investigation and experimental stages, the subsequent phase in the implementation of the Problem-Based Learning (PBL) model involved the development and presentation of their work results. At this stage, students were required to compile comprehensive reports that documented the processes, findings, and conclusions derived from their collaborative inquiry. The preparation of such reports served as a means of training

students to communicate their research outcomes in a structured, logical, and scientifically coherent manner (Indri et al., 2020; Restiana & Djukri, 2021). Each report was designed to include essential components such as the background of the problem, research objectives, methodology, data analysis, conclusions, and references. Through this structured writing process, students were expected to strengthen their scientific writing competence and internalize systematic reasoning patterns that are fundamental for their future roles as professional educators. In addition to enhancing cognitive abilities, the report preparation process contributed to the development of affective and psychomotor dimensions particularly academic responsibility, intellectual integrity, and scientific discipline (Hoque, 2016).

During this stage, continuous guidance was provided by the lecturer to ensure the academic quality and coherence of students' written outputs. The lecturer offered feedback on the structure, content, methodological accuracy, and citation consistency to ensure that the reports adhered to scholarly standards. This process also encouraged students to reflect on the steps they had undertaken, critically evaluate their decision-making during the investigation, and identify areas for improvement (Alt & Raichel, 2022; Maftuh, 2023). Following the report-writing phase, students were required to present their findings to their peers and lecturers. This presentation session served as a platform for students to articulate their arguments, defend their interpretations, and engage in academic dialogue. The experience provided an opportunity for students to develop self-confidence, public speaking competence, and scientific communication skills attributes that are essential for prospective teachers.

As one lecturer remarked "*... in learning, students are also challenged to answer various questions, accept criticism, and provide clarification on the data and methods used. The interactive discussion created from this presentation trains them to think quickly to respond and defend their opinions based on work results*". (Interview. LCT.004)

Feedback from both peers and lecturers was considered an integral component of this process, as it facilitated revision, refinement, and validation of the final reports before submission. These dialogic interactions not only enhanced the accuracy and depth of students' analyses but also cultivated a reflective academic culture rooted in evidence-based reasoning. Overall, the activities of report preparation and result presentation represent critical stages within the PBL framework. They function not merely as assessment components but as pedagogical instruments that nurture students' scientific competence, critical thinking, and professional communication skills (Celik, 2022; Gizaw & Sota, 2023). Such competencies are essential for future educators, who are expected not only to master disciplinary content but also to facilitate inquiry-based learning and guide students in constructing knowledge through scientific reasoning.

Hence, the integration of reporting and presentation stages within the PBL model contributes significantly to the development of contextual and authentic learning experiences, aligning with the principles of a competency-based curriculum and the broader objectives of 21st-century education (Bell, 2010; Miller et al., 2023).

Analyzing and Evaluating the Problem-Solving Process

The final stage in the implementation of the Problem-Based Learning (PBL) model involves the processes of analysis and evaluation, during which both students and lecturers engage in reflective activities to review the entire sequence of problem-solving that has been undertaken. At this point, students are guided to critically assess the stages they have completed ranging from information gathering, experimentation, and data analysis to the presentation of results (Ardiansyah et al., 2024; Gao et al., 2022). The primary objective of this phase is to help students establish meaningful connections between theoretical concepts and the empirical findings derived from their investigations, as well as to identify aspects that require improvement for more effective problem resolution in future learning cycles. Reflection serves as a key component of this stage, enabling

students to revisit each phase of their learning process, recognize challenges encountered, and evaluate the strategies employed to address them. Through this reflective process, students are able to identify the strengths and weaknesses of their research design, understand how the applied approach contributed to learning outcomes, and consider alternative strategies for improvement (Ardiansyah et al., 2022; Cahyanto et al., 2024).

In addition to personal reflection, students are encouraged to analyze the interrelationships among various elements of their work namely, theoretical frameworks, experimental data, and conclusions presented in their reports. They are guided to categorize findings based on thematic relevance, identify emerging patterns, and interpret relationships among variables within a theoretical context. Lecturers play a facilitative role by assisting students in identifying critical components that substantiate their experimental results and by guiding them toward potential directions for further investigation. Moreover, students are instructed to formulate recommendations grounded in their empirical findings, particularly within the context of science learning in elementary schools. These recommendations are expected to be both realistic and applicable, contributing to the advancement of pedagogical practices in the field.

As noted by one lecturer, “... *in the learning reflection session, my students were given the opportunity to ask questions and express their opinions regarding the work results of other groups. This process is expected to encourage students to re-analyze the solutions produced and critically consider each step they have taken*”. (Interview. LCT.005)

Subsequently, students and lecturers collaboratively summarized the results of the problem-solving process. Students were encouraged to formulate comprehensive conclusions that encapsulated the key points of discussion, proposed solutions, and identified areas for further improvement. The culmination of this stage involved a meta-evaluation of the learning process itself assessing not only the effectiveness of the PBL implementation but also the extent to which students developed conceptual understanding, practical skills, and collaborative competence (Cahyanto et al., 2024). Lecturers acknowledged students' engagement and provided constructive feedback to enhance their future learning practices. This evaluative process was generally conducted through class discussions, allowing for collective reflection and peer exchange that deepened students' comprehension and self-awareness. The integration of such reflective evaluations is considered instrumental in cultivating metacognitive and critical thinking abilities essential for professional educators (Arifin et al., 2020; Calma & Davies, 2025; Rini et al., 2020).

Overall, the comprehensive implementation of the PBL model has demonstrated substantial contributions to the development of a holistic learning experience encompassing cognitive, affective, and psychomotor domains. Within this model, students are not merely required to master theoretical concepts but are also encouraged to contextualize their knowledge through engagement with authentic problems relevant to the elementary education environment. Furthermore, the reflective and evaluative nature of PBL fosters learner autonomy and encourages students to continuously refine their learning strategies and adopt more effective approaches to inquiry and problem solving. Such practices align closely with the principles of 21st-century education, which emphasize higher-order thinking skills, creativity, and adaptability to dynamic professional contexts (Alsaleh, 2020; Romero Ariza et al., 2024). Hence, the PBL model not only equips students with content mastery but also prepares them to become innovative, reflective, and competent educators capable of addressing the evolving challenges of contemporary elementary education.

Impact of the Implementation of the Problem-Based Learning Model

Increasing Critical Thinking Skills

The findings of this study indicate that the implementation of the Problem-Based Learning (PBL) model in the Natural Science course effectively enhances students' critical thinking skills.

The learning process, which begins with the presentation of contextual and authentic problems, encourages students to identify the essence of the problem systematically and logically (Calma & Davies, 2025; Tang et al., 2020). Observational data revealed that most students demonstrated the ability to formulate problems accurately and construct logical reasoning in response to the cases presented by lecturers. Furthermore, interview results highlighted that students felt more challenged to think deeply and avoid drawing premature conclusions suggesting that the process of critical thinking was gradually nurtured throughout the stages of PBL.

As one student reflected “... *we feel more motivated to understand the existing problems in depth, because we are required to carry out various structured activities such as conducting literature reviews, discussions, and reflections. This makes us accustomed to analyzing from various perspectives and not rushing to conclude something. In addition, in interactive learning, it makes us more confident in expressing opinions based on group work results, not just personal opinions*”. (Interview. STD.001)

This emerging ability to think critically aligns with the framework proposed by Ahern et al. (2019) and Puig et al. (2019), which conceptualizes critical thinking as a cognitive process involving the identification of arguments, evaluation of evidence, and decision-making based on logical and reflective reasoning. Within the context of PBL, students are not passive recipients of information; rather, they are actively involved in searching for data, reviewing literature, and connecting empirical evidence with theoretical constructs (Seibert, 2021; Miller et al., 2023). Document analysis further supports these findings, showing that students were able to present detailed descriptions of the information collected and effectively integrate empirical data with scientific principles relevant to the topic under study. These activities reflect engagement in higher-order cognitive processes, including analysis, synthesis, and evaluation core dimensions of critical thinking.

Moreover, the findings reveal that students were capable of evaluating multiple alternative solutions using systematic and evidence-based reasoning. They formulated hypotheses and proposed solutions, compared their feasibility, and justified their arguments with sound theoretical and empirical bases. Group discussions provided an avenue for students to critique peers' ideas constructively, defend their arguments logically, and remain open to feedback. Such interactions embody the characteristics of scientific discourse and illustrate the students' growing ability to evaluate ideas and arguments objectively an essential component of critical thinking (Tang et al., 2020).

In the final reflection stage, students reported that the PBL approach had a transformative effect on their way of thinking. They acknowledged that the structured inquiry and reflection process encouraged them to evaluate information critically and develop independence in generating problem-solving strategies. Lecturers also played a pivotal role in this process by acting as facilitators posing guiding questions, providing direction, and ensuring that students used credible and relevant sources. Overall, these findings underscore that the implementation of the Problem-Based Learning model significantly enhances students' critical thinking competencies. The improvement is evident across various dimensions, including problem identification, data analysis, argument construction, and evidence-based decision-making. Such outcomes align with the findings of previous studies (Darwin et al., 2024; Lorencova et al., 2019), which consistently emphasize that PBL fosters students' ability to reason analytically, evaluate evidence critically, and make scientifically responsible judgments in learning contexts.

Increasing Students' Science Process Skills

The findings of this study demonstrate that the implementation of the Problem-Based Learning (PBL) model significantly enhances students' basic science process skills, which encompass the abilities to observe, measure, classify, predict, infer, and communicate (Astalini et al., 2023; Indri et al., 2020). Observational data revealed that students became more actively engaged in learning activities, particularly when confronted with natural phenomena that required

direct investigation. During these sessions, students exhibited strong observational skills, carefully identifying key characteristics and patterns related to the phenomena under study. This process not only strengthened their basic scientific abilities but also stimulated curiosity and deeper inquiry into the observed events.

The development of measurement and classification skills was also evident throughout the learning process. Students demonstrated greater accuracy in using laboratory instruments and collecting data relevant to their experimental tasks. They were able to compare empirical findings with theoretical expectations and evaluate any discrepancies that emerged (Yuliskurniawati et al., 2019). In addition, when classifying experimental results, students successfully grouped data or objects according to their specific characteristics, reflecting their growing understanding of systematic categorization. These findings align with Tanti et al. (2020), who argue that science process skills represent higher-order intellectual abilities developed through meaningful, inquiry-based learning experiences.

The aspects of prediction and inference also showed substantial progress, indicating improvement in students' logical and analytical thinking. When asked to hypothesize the outcomes of an experiment, students were able to draw upon relevant scientific concepts and prior experiences as a foundation for reasoning (Apaivatin et al., 2021). Their conclusions were increasingly systematic, supported by data-driven arguments, and framed within appropriate theoretical contexts. As highlighted by Gizaw and Sota (2023), such processes represent an active form of knowledge construction in which learners discover relationships between empirical data and scientific principles through exploration and reflection.

In terms of communication skills, students demonstrated clear progress in presenting and reporting their findings. Through structured group presentations and written reports, students effectively articulated their understanding using accurate scientific terminology and logical argumentation supported by empirical evidence. These findings correspond with the perspective of Darwin et al. (2024), who emphasize that social interaction and dialogic exchange play a crucial role in shaping scientific reasoning and cognitive development.

Group discussions, presentations, and interactive question-and-answer sessions provided opportunities for students to articulate ideas, defend interpretations, and receive constructive feedback from peers and lecturers further reinforcing conceptual understanding. Consequently, the Problem-Based Learning model not only facilitated conceptual mastery of Natural Science content but also strengthened essential scientific skills required for systematic inquiry and experimentation (Celik, 2022; Mushani, 2021).

Overall, PBL fosters active, inquiry-driven learning experiences that promote scientific reasoning through exploration, collaboration, and reflection. The structured problem-solving process within PBL encourages students to become independent learners capable of analyzing and resolving problems systematically. These findings confirm that the PBL model is highly relevant for pre-service teacher education, as it equips future educators with essential 21st-century competencies particularly critical thinking, problem-solving, and scientific literacy. Based on these findings, students' development in critical thinking and science process skills is further illustrated through the learning indicators summarized in Table 3.

Table 3. Observation Results in Learning

Aspects observed	Indicator	Visible behavior
Critical Thinking Skills	Ability to identify problems	Students are able to identify the core of the problem by formulating key questions that reflect their understanding of the context. Problems are expressed coherently and logically and are connected to relevant concepts or theories.
	Ability to analyze information in depth	Students systematically describe information collected from multiple sources, including facts, data, and findings relevant to the problem. They demonstrate the ability to link this information with scientific theories or concepts, resulting in meaningful and in-depth analysis.
	Ability to evaluate and compare arguments	Students evaluate alternative solutions objectively, considering their advantages and disadvantages. Constructive criticism is provided for inadequate solutions, while more effective approaches are compared based on scientific evidence and logical reasoning.
	Ability to draw logical and relevant conclusions	Students formulate conclusions based on valid data and analyses that are relevant to the problems studied. Conclusions follow a logical sequence and demonstrate an understanding of the relationship between data, theory, and proposed solutions.
	Ability to make decisions based on data and facts	Decisions are made based on systematic analysis of data and facts collected during learning. Students consider multiple alternatives and their potential impacts, ensuring objectivity and rationality in decision-making.
Science Process Skills	Ability to observe and record phenomena	Students observe phenomena carefully and record changes or symptoms in detail, both qualitatively and quantitatively. Observations are thorough and provide a strong basis for analysis and conclusion.
	Ability to formulate predictions in experiments	Students formulate hypotheses relevant to the problem, grounded in scientific theories or concepts. Predictions are logical, specific, and testable through systematically designed experiments.
	Ability to design and carry out experiments	Experimental procedures are designed systematically, with attention to the sequence of steps, tools, and materials. Implementation is carried out precisely according to plan, ensuring results are scientifically valid.
	Ability to collect and analyze data	Students organize and process experimental data systematically. Analyses are conducted using appropriate scientific methods, resulting in logical interpretations that support problem-solving.

Aspects observed	Indicator	Visible behavior
	Ability to communicate experimental results scientifically	Experimental results are presented systematically and clearly, both in written reports and oral presentations. Findings are supported by relevant data, ensuring scientific rigor and clarity.

Thus, the implementation of the Problem-Based Learning (PBL) model was found to not only enhance students' conceptual understanding of the material in the Natural Science course but also to strengthen their critical thinking and science process skills (Darwin et al., 2024; Setiawan & Sugiyanto, 2020). Students demonstrated significant improvement in systematically observing natural phenomena, accurately measuring and recording data, logically classifying information, making rational predictions, drawing coherent conclusions, and effectively communicating their findings. These competencies represent essential components of scientific inquiry and are crucial for developing analytical reasoning and problem-solving abilities. Furthermore, such skills are indispensable in preparing students to become future elementary school teachers who are capable of adopting transformative, inquiry-oriented approaches in their professional practice (Almazroui, 2023; Cahyanto et al., 2024).

CONCLUSION

Based on the findings of this study, it can be concluded that the implementation of the Problem-Based Learning (PBL) model in the Natural Science course has made a significant contribution to enhancing students' critical thinking and science process skills within the Islamic Elementary School Teacher Education Study Program, Faculty of Islamic Studies, Universitas Islam Malang. Through the systematic stages of problem orientation, organization of learning activities, investigation guidance, development of work outputs, and evaluation of the learning process, students were actively engaged in learning experiences that emphasized analytical reasoning, synthesis, and reflective thinking. The descriptive qualitative approach employed in this research effectively captured the depth of students' engagement in developing higher-order thinking and applicable scientific competencies. The results of this study not only reinforce empirical evidence regarding the effectiveness of the PBL model in higher education but also provide practical implications for the design of more contextual, inquiry-based curricula aligned with 21st-century competency frameworks. Future research is recommended to explore the long-term effects of PBL on students' preparedness for teaching practice and its role in strengthening professional identity and reflective character among prospective teachers.

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