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The Effect of Problem-Based Learning Integrated with Digital Literacy on Junior High School Students' Science Learning Outcomes on the Topic of the Earth's Structure and Its Development

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ABSTRACT

Science education in the 21st century requires the application of instructional models that not only enhance conceptual mastery but also develop students' ability to critically utilize digital information. However, teaching practices in schools are still dominated by conventional methods, resulting in the suboptimal use of digital literacy in the learning process. This study aims to analyze the effect of Problem-Based Learning (PBL) integrated with digital literacy on the science learning outcomes of junior high school students on the topic of Earth's Structure and Its Development. The study employed a quantitative approach using a pre-experimental method through a One-Group Pretest–Posttest Design. The research subjects consisted of 25 eighth-grade junior high school students selected using total sampling. The research instrument was a learning outcome test that met the criteria for validity and reliability. Data were analyzed using descriptive statistics, the Shapiro–Wilk test, a paired-sample t-test, and N-Gain. The results showed that the students' average score increased from 47.87 on the pretest to 69.52 on the posttest. The results of the paired-sample t-test showed a significance value of 0.004 ($p < 0.05$), indicating a significant difference in learning outcomes before and after the intervention. In addition, an N-Gain value of 0.6658 was obtained, falling into the moderate–high category, indicating that the implementation of PBL integrated with digital literacy is quite effective in improving science learning outcomes. These findings suggest that integrating digital literacy into every stage of PBL can increase student engagement in the learning process, strengthen conceptual understanding, and serve as an alternative science learning strategy relevant to 21st-century competency requirements.

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INTRODUCTION

Natural Sciences is one of the subjects that plays a crucial role in developing scientific literacy, critical thinking skills, problem-solving, and evidence-based decision-making. Within the framework of 21st-century education, science learning is no longer focused solely on mastering concepts but is also aimed at equipping students with the ability to identify problems, analyze scientific information, evaluate evidence, and apply knowledge to solve various real-life problems (OECD, 2023). The Programme for International Student Assessment (PISA) framework emphasizes that science education must develop students' ability to explain phenomena scientifically, design investigations, and interpret data as the basis for responsible decision-making (OECD, 2023). Therefore, the science learning process must be designed through active, contextual, collaborative, and student-centered learning experiences to optimally develop 21st-century competencies.

Advances in digital technology have transformed the way students acquire, process, and utilize information in the learning process. This situation has made digital literacy one of the essential competencies that must be integrated into learning. UNESCO (2024) explains that digital literacy is not only related to the ability to operate digital devices but also encompasses the ability to search for, evaluate, manage, integrate, and communicate information critically, ethically, and responsibly. In the context of science education, digital literacy enables students to access various sources of scientific information, virtual simulations, conceptual visualizations, and real-world data that support their understanding of scientific phenomena. Various research findings indicate that the integration of digital technology into learning can increase student engagement, strengthen conceptual understanding, and foster the development of higher-order thinking skills (Chourio-Acevedo et al., 2024; Raharja et al., 2025; Sirojjuddin et al., 2025; Wugaje et al., 2023).

Nevertheless, the implementation of science education in schools still faces various challenges. Preliminary observations at Junior High School … indicate that the learning process is still dominated by lecture-based methods, with textbooks serving as the primary learning resource. The use of digital learning resources has not been optimized, so students tend to passively receive information without sufficient opportunities to explore various scientific sources or solve problems independently. This situation results in low student engagement during the learning process and suboptimal science learning outcomes, particularly regarding the topic "Earth's Structure and Its Development." This subject matter is complex because it involves abstract concepts regarding the Earth's internal structure, lithosphere dynamics, geological activity, and the interrelationships among natural processes that are difficult to observe directly. Therefore, a learning model is needed that can connect these concepts to real-world phenomena through the use of various credible digital information sources.

One learning model considered capable of addressing these challenges is Problem-Based Learning (PBL). This model places students at the center of learning through the resolution of contextual problems that encourage inquiry, discussion, collaboration, scientific communication, and reflection. Various studies indicate that the implementation of PBL has a positive impact on students' learning outcomes, critical thinking skills, problem-solving abilities, and science literacy (Uluçınar, 2023; Rahman et al., 2024; Yaşar et al., 2024). On the other hand, research on technology-based learning indicates that the use of digital media, e-modules, and web-based learning resources can enhance students' learning motivation, the quality of their learning experiences, and their conceptual understanding (Sirojjuddin et al., 2025; Raharja et al., 2025). Research by Fitriani et al. (2021) also shows that the use of learning models supported by instructional media can improve motivation and learning outcomes in science. Furthermore, Hidayat et al. (2020) report that misconceptions in science learning are still frequently encountered, necessitating instructional strategies that can help students construct concepts in a more meaningful way.

A review of various studies shows that the effectiveness of Problem-Based Learning and digital literacy has been extensively examined in science education. However, most studies still treat digital literacy as a supporting medium or learning resource, rather than as a competency systematically integrated into every stage of the PBL process. On the other hand, research on Problem-Based Learning integrated with digital literacy in the topic "Earth's Structure and Development" at the junior high school level remains relatively limited. In fact, the nature of this subject matter requires students to be able to search for, evaluate, and interpret various scientific information from digital sources to comprehensively explain geological phenomena. Thus, there remains a research gap regarding how the integration of digital literacy into each stage of Problem-Based Learning can influence students' science learning outcomes. Recent meta-analyses also indicate that the integration of digital technology into problem-based learning remains a key direction for the development of science education research that requires more empirical evidence across various learning contexts (Yaşar et al., 2024; Usman et al., 2025).

Based on the above discussion, this study aims to analyze the effect of Problem-Based Learning integrated with digital literacy on the science learning outcomes of junior high school students in the topic "The Earth's Structure and Its Development." This study is expected to make a theoretical contribution to the development of a science learning model that integrates problem-based learning with digital literacy, while also providing practical alternatives for teachers in designing more contextual, interactive, and student-centered learning experiences.

METHOD

This study employed a quantitative approach using a pre-experimental method through a One-Group Pretest–Posttest Design to analyze the effect of implementing Problem-Based Learning (PBL) integrated with digital literacy on students' science learning outcomes. This research design was chosen because it allows for the measurement of changes in students' learning outcomes before and after they were exposed to instruction using the PBL model integrated with digital literacy.

The study was conducted at Junior High School (SMPTK N Sorong) during the even semester of the 2025/2026 academic year. The research subjects consisted of 25 eighth-grade students selected using total sampling, as the entire population was included as the research sample. The independent variable in this study was the implementation of Problem-Based Learning integrated with digital literacy, while the dependent variable was students' science learning outcomes on the topic of "Earth's Structure and Its Development."

The learning process is implemented following the Problem-Based Learning (PBL) framework, which consists of five stages: (1) orienting students to the problem, (2) organizing students for learning, (3) guiding individual and group investigations, (4) developing and presenting solutions to the problem, and (5) analyzing and evaluating the problem-solving process. Digital literacy is integrated into every stage of learning through the use of various credible digital learning resources, such as popular science articles, educational videos, interactive simulations, and relevant educational websites. Students not only access digital information but are also guided to evaluate the credibility of sources, compare information from various references, interpret data, and use that information as a basis for solving the given problems.

The research instrument consisted of a multiple-choice learning achievement test administered before (pretest) and after (posttest) the intervention. Before use, the instrument underwent validity and reliability testing to ensure it met the criteria for a valid measure of learning achievement suitable for use in this study. The research data were analyzed using descriptive statistics to describe the students' learning outcomes. A normality test was conducted using the Shapiro–Wilk test because the sample size was less than 50 students. Subsequently, hypothesis testing was performed using a paired-sample t-test at a 5%

significance level to determine differences in learning outcomes before and after the intervention. The magnitude of the improvement in learning outcomes was analyzed using N-Gain, which was classified into high (≥ 0.70), moderate (0.30–0.69), and low (< 0.30) categories based on Hake's (1999) criteria.

RESULTS AND DISCUSSION

Students' Science Learning Outcomes

The implementation of Problem-Based Learning (PBL) integrated with digital literacy was conducted over four instructional sessions on the topic *Earth's Structure and Its Development*. Throughout the learning process, students were actively engaged in identifying contextual geological problems, searching for information from credible digital resources, analyzing scientific evidence, discussing alternative solutions collaboratively, and presenting the results of their investigations. Unlike conventional teacher-centered instruction, the learning process emphasized inquiry, collaboration, and evidence-based reasoning supported by digital information sources.

Student learning outcomes were measured using a pretest administered before the intervention and a posttest administered after the completion of the instructional program. The descriptive statistics of students' learning outcomes are presented in Table 1.

Table 1. Descriptive Statistics of Student Learning Outcomes

Statistic	Pretest	Posttest
Mean	47.87	69.52
Median	44	70
Standard deviation	11.68	7.19
Minimum	28	56
Maximum	75	80

To provide a clearer illustration of students' learning improvement, the comparison of average pretest and posttest scores is presented in Figure 1.

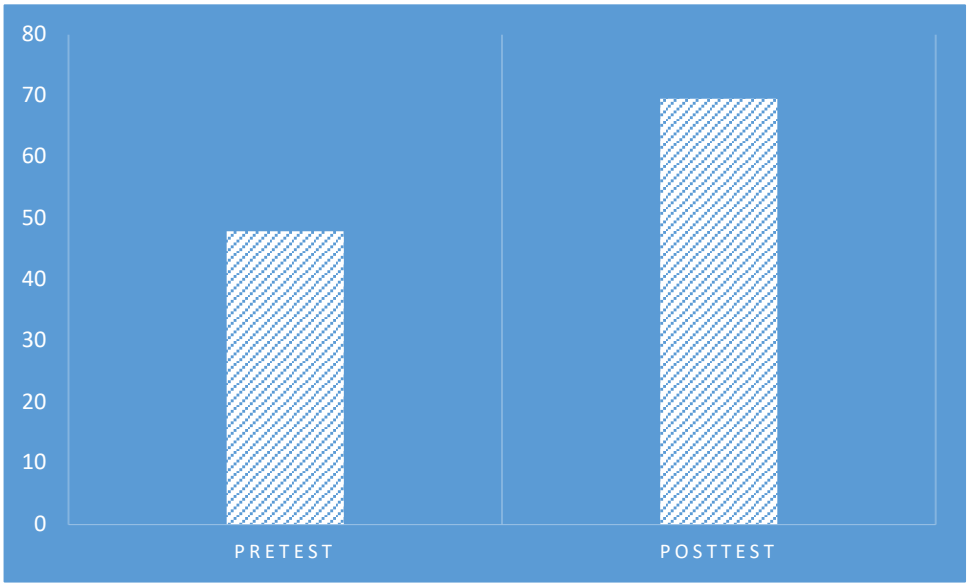

Figure 1. Comparison of Students' Average Pretest and Posttest Scores

As shown in Table 1 and Figure 1, the average student score increased substantially from 47.87 on the pretest to 69.52 on the posttest, representing an improvement of more than 21 points. This finding indicates that students developed a considerably better conceptual understanding of Earth's Structure and Its Development after participating in learning activities based on PBL integrated with digital literacy. Furthermore, the decrease in the standard deviation from 11.68 to 7.19 suggests that students' learning achievements became more homogeneous following the intervention. In other words, the instructional approach not only

improved the overall level of achievement but also reduced the performance gap among students, indicating that the learning model benefited students with varying academic abilities.

The improvement in learning outcomes can be explained by the characteristics of Problem-Based Learning, which positions students as active constructors of knowledge rather than passive recipients of information. Throughout the instructional process, students were encouraged to investigate authentic geological phenomena, formulate hypotheses, gather supporting evidence from multiple digital resources, evaluate the reliability of information, and collaboratively develop scientifically justified solutions. These learning activities encouraged students to actively organize and reconstruct their prior knowledge, allowing conceptual understanding to develop through meaningful cognitive engagement.

From the perspective of constructivist learning theory, meaningful learning occurs when learners actively construct new knowledge based on previous experiences through interaction with authentic learning environments. The integration of digital literacy further enriched this learning process by expanding students' access to scientific information beyond textbooks. Instead of relying solely on teacher explanations, students explored videos, digital articles, interactive visualizations, and educational websites to verify scientific concepts and compare multiple explanations of geological phenomena. Such activities promoted deeper conceptual understanding because students continuously evaluated, synthesized, and interpreted information before reaching conclusions.

Another important finding is that digital literacy functioned not merely as a technological aid but as an essential cognitive component within the learning process. During problem investigation, students were required to identify trustworthy information, distinguish scientific facts from unsupported opinions, and justify their arguments using evidence collected from credible digital resources. Consequently, students simultaneously developed conceptual understanding, information evaluation skills, and scientific reasoning abilities. This finding suggests that integrating digital literacy into every stage of PBL transforms technology from a passive instructional medium into an active learning instrument that supports inquiry and evidence-based reasoning.

The present findings are consistent with the meta-analysis conducted by Uluçınar (2023), which concluded that Problem-Based Learning significantly improves students' academic achievement in science education by promoting inquiry-oriented learning experiences. Similarly, Rahman et al. (2024) reported that PBL positively influences higher-order thinking skills, conceptual understanding, and science achievement. The findings also support those of Chourio-Acevedo et al. (2024), who emphasized that digital literacy enhances learners' ability to access, evaluate, and utilize information critically. Furthermore, studies by Sirojjuddin et al. (2025) and Raharja et al. (2025) demonstrated that integrating digital technologies into science instruction increases student engagement, promotes conceptual understanding, and creates more interactive learning environments. Collectively, these studies reinforce the conclusion that combining inquiry-based learning with digital literacy provides synergistic benefits for science learning.

The findings also have important implications for science education. Contemporary science instruction should no longer position digital technology merely as a presentation tool but should integrate digital literacy into inquiry-based learning activities. Such integration enables students to develop scientific knowledge alongside essential twenty-first-century competencies, including critical thinking, information literacy, collaboration, communication, and evidence-based decision-making. Consequently, the integration of digital literacy within the PBL framework represents an instructional innovation capable of supporting meaningful science learning while simultaneously preparing students for the challenges of an increasingly digital society.

The Effect of Problem-Based Learning Integrated with Digital Literacy on Learning Outcomes

Before testing the hypotheses, the learning outcome data were tested using the Shapiro–Wilk normality test. The test results showed that the posttest data had a significance value of 0.134 ($p > 0.05$), thus meeting the assumption of normality and making them suitable for analysis using parametric tests. Next, the effect of implementing PBL integrated with digital literacy on learning outcomes was analyzed using a paired-sample t-test. The test results are presented in Table 2.

Table 2. Paired t-Test Results

Variable	Value
Sig. (2-tailed)	0.004

A p-value of 0.004 which is smaller than the significance level of 0.05, indicates that there is a significant difference between learning outcomes before and after the implementation of PBL integrated with digital literacy. Thus, the research hypothesis is accepted, meaning that the implementation of this model has a positive effect on students' science learning outcomes.

This improvement in learning outcomes was not only due to the use of the PBL model but also to the systematic integration of digital literacy into each learning sequence. Students did not merely receive information from the teacher but actively sought out, evaluated, and compared information from various digital sources before formulating solutions to the problems presented. These activities fostered critical thinking skills while simultaneously strengthening students' digital literacy as part of the learning process.

These findings reinforce the results of the study by Chourio-Acevedo et al. (2024), which state that digital literacy enhances students' ability to critically evaluate and use information. Furthermore, the results of this study also support the findings of Yaşar et al. (2024), which show that the effectiveness of PBL increases when combined with learning strategies that encourage independent exploration of information and inquiry.

Effectiveness of Instruction Based on N-Gain

In addition to hypothesis testing, the effectiveness of instruction was analyzed using N-Gain to determine the extent of improvement in students' learning outcomes after participating in the instruction.

Table 3. Results of the N-Gain Analysis

Variable	Value
Average N-Gain	0.665
Gain percentage	66.5%
Categories	Medium - high

Based on Table 3, the N-Gain value was 0.665, or 66.5%, which falls into the moderate–high category. These results indicate that the implementation of PBL integrated with digital literacy is quite effective in improving students' learning outcomes on the topic of "Earth's Structure and Its Development."

This improvement indicates that the learning process not only produced statistically significant changes but also led to a meaningful enhancement in conceptual understanding. The abstract nature of the "Earth's Structure" material becomes easier to understand when students have the opportunity to explore various digital resources, observe visualizations of geological phenomena, and discuss their findings in groups. These activities allow students to build connections between scientific concepts and real-world phenomena, thereby making learning more meaningful.

The results of this study are consistent with the research by Sutrisna and Sasmita (2022), which showed that PBL can improve science learning outcomes through collaborative problem-solving activities. Furthermore, Komang's (2024) study indicates that the use of digital literacy-based media contributes to improved learning outcomes because students gain

a more interactive learning experience. Thus, the integration of digital literacy into the PBL framework is one of the factors that enhances the effectiveness of science learning, particularly for topics that require the visualization and exploration of scientific information.

CONCLUSION

This study shows that the implementation of Problem-Based Learning (PBL) integrated with digital literacy has a positive and significant effect on students' science learning outcomes regarding the topic "The Earth's Structure and Its Development." The improvement in learning outcomes is evidenced by an increase in the average score from 47.87 on the pretest to 69.52 on the posttest, accompanied by an N-Gain value of 0.6658—which falls into the moderate-to-high category—as well as the results of a paired-sample t-test showing a significance value of 0.004 ($p < 0.05$). These findings indicate that integrating digital literacy into the Problem-Based Learning (PBL) framework can enhance students' conceptual understanding while also leading to more equitable learning outcomes.

Keberhasilan pembelajaran tidak hanya dipengaruhi oleh penerapan model Problem Based Learning, tetapi juga oleh pemanfaatan literasi digital secara sistematis dalam setiap tahapan pembelajaran. Kegiatan mencari, mengevaluasi, dan memanfaatkan informasi dari berbagai sumber digital yang kredibel mendorong peserta didik untuk lebih aktif membangun pengetahuan, berdiskusi secara ilmiah, serta mengembangkan kemampuan berpikir kritis dalam menyelesaikan permasalahan kontekstual. Dengan demikian, integrasi Problem Based Learning dan literasi digital dapat menjadi alternatif strategi pembelajaran IPA yang relevan dengan tuntutan kompetensi abad ke-21.

Penelitian ini masih memiliki keterbatasan karena menggunakan desain one-group pretest–posttest dengan jumlah sampel yang relatif terbatas dan dilaksanakan pada satu sekolah. Oleh karena itu, penelitian selanjutnya disarankan menggunakan desain eksperimen yang melibatkan kelompok kontrol, jumlah sampel yang lebih besar, serta mengkaji pengaruh integrasi literasi digital dalam Problem Based Learning terhadap kemampuan lain, seperti literasi sains, keterampilan berpikir kritis, kemampuan pemecahan masalah, maupun keterampilan kolaborasi pada berbagai materi IPA.

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