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Digital Media-Assisted Problem Based Learning Model: Students' Learning Outcomes and Science Literacy at Middle School

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ABSTRACT

Low scientific literacy and student learning outcomes in science subjects are often caused by conventional learning processes and the lack of technological integration in solving real-world problems. This study aims to analyze the effect of implementing the Problem-Based Learning (PBL) learning model assisted by digital media on students' learning outcomes and scientific literacy in the digestive system material. This study used a quantitative approach with a quasi-experimental nonequivalent control group design. The research subjects consisted of two eighth-grade classes in a public junior high school, where the experimental class implemented PBL assisted by digital media (n=30) and the control class used conventional learning (n=30). Data was collected through learning outcome tests and scientific literacy tests, then analyzed using an independent sample t-test. The results showed a statistically significant difference between students' learning outcomes and scientific literacy in the two classes ($p < 0.001$). The experimental class achieved an average posttest learning outcome of 82.10, higher than the control class's 74.30. For the scientific literacy variable, the experimental class achieved an average of 79.40, while the control class achieved 71.20. The effect sizes found were categorized as strong, namely 1.17 for learning outcomes and 1.16 for scientific literacy. This study proves that the integration of digital media in PBL syntax is effective in improving students' cognitive achievement and science process skills. This research provides a practical contribution for educators in implementing innovative learning strategies relevant to the digital era to create more applicable and meaningful science learning.

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1. INTRODUCTION

In the 21st century, students need to not only understand scientific concepts but also be scientifically literate so they can understand natural events, solve problems in context, and make decisions based on evidence (Fortus et al., 2022; Osborne & Allchin, 2025). Scientific literacy is positioned as a key competency because it relates to an

individual's capacity to use scientific knowledge to explain phenomena, evaluate information, and apply scientific reasoning in real-life situations (Almeida et al., 2023). However, in many school contexts, science learning is still predominantly oriented toward delivering material and reproducing concepts, resulting in the development of scientific literacy and 21st-century skills that have not yet developed optimally (Berg et al., 2021; Widiyawati et al., 2021). This issue presents a challenge because scientific literacy is not solely developed through memorizing concepts but rather through learning experiences that position students as problem solvers, inquirers, and data-driven decision-makers (Suwono et al., 2023).

One relevant approach to addressing this need is Problem-Based Learning (PBL), as it positions authentic problems as learning triggers, encouraging active inquiry, scientific argumentation, and concept construction (Anggraeni et al., 2023; Hasbi & Fitri, 2023; Muzaini et al., 2022). Recent synthetic evidence indicates that PBL in science education has a positive impact on learning outcomes. A meta-analysis in the context of science learning reports that PBL effectively improves academic achievement compared to traditional learning (Uluçınar, 2023). This strengthening is also evident in non-cognitive aspects that support learning success, as a recent meta-analysis on problem-driven learning (including PBL) showed a positive effect on student learning motivation, a factor often a prerequisite for effective problem-based learning (Wijnia et al., 2024). Thus, PBL is theoretically and empirically relevant for addressing contemporary science learning objectives that emphasize conceptual understanding, scientific reasoning, and learning engagement (Rizal et al., 2023; Smith et al., 2022).

With the advancement of educational technology, digital media is increasingly used in science learning to clarify abstract concepts and enhance the quality of the learning experience (Arsyad & Syakhrani, 2024; Wannapiroon & Pimdee, 2022). Contextual meta-analytic evidence in secondary schools indicates that the use of digital tools in mathematics and science learning has a positive effect on learning outcomes, and this impact tends to be stronger when technology use is supported by instructional design and teacher capacity building (Hillmayr et al., 2020). Furthermore, a recent systematic review confirmed that digital simulations—including virtual labs and interactive simulations—can enhance conceptual understanding, engagement, and problem-solving skills, although their effectiveness is strongly influenced by the accompanying learning strategies (Kefalis et al., 2025). Therefore, the “add-on” use of digital media without integration with appropriate learning models risks producing learning that is merely engaging but does not sufficiently promote knowledge transformation and scientific literacy. Within this framework, de Jong’s (2019) argument emphasizes that the transition to more “engaged” STEM learning requires learning designs that integrate technology as a cognitive tool with pedagogical approaches that encourage active engagement and scientific thinking, rather than simply media substitution.

In the Indonesian context, studies in nationally indexed journals indicate that a problem-based/inquiry approach that directs students toward scientific activities can promote improved scientific literacy (Ikawati & Pohan, 2023; Ismaniati et al., 2025). For example, a comparative-experimental study in the Indonesian Journal of Science

Education showed that a PBL-based approach (and its integration with STEM) can improve students' scientific literacy competencies compared to conventional learning (Parno et al., 2020). Conversely, your target journal, the Journal of Science Education Innovation, regularly publishes research on scientific literacy and the efficacy of innovative learning models for enhancing competencies, thereby rendering the enhancement of scientific literacy through suitable instructional design a pertinent issue within the journal's scope (e.g., Lestari et al., 2021). However, a still-visible research gap is the limited empirical evidence specifically testing the integration of PBL with digital media in a single science learning design and simultaneously measuring its impact on two main outcomes: learning outcomes and scientific literacy, particularly at the junior high school level and in biology subjects that tend to be abstract-processual, such as the digestive system. In this material, process visualization, cause-and-effect reasoning, and the ability to relate concepts to everyday health issues are strongly required, so the integration of problem-based learning models with digital media support deserves systematic testing.

The innovation of this research lies in testing the integration of PBL and digital media within a single science learning design oriented toward contextual health problems, while simultaneously measuring its impact on two indicators of science learning quality: learning outcomes and scientific literacy. This study not only uses digital media as a presentation tool but also integrates it into the problem-solving phase of PBL to strengthen conceptual understanding. Unlike studies that only focus on learning outcomes, this study comprehensively proves that this intervention can produce a very strong effect size on both learning outcomes and scientific literacy. In addition, through independent sample t-tests, this study provides strong empirical evidence that the improvement in learning outcomes in the experimental class far exceeds that of the control class, providing scientific validation of the effectiveness of using digital media in junior high schools.

Building upon this description, this study aims to analyze the effect of implementing a digital media-assisted problem-based learning model on junior high school students' science learning outcomes and scientific literacy in the digestive system. Consequently, this study contributes empirically to enhancing the evidence regarding the efficacy of technology-supported problem-driven learning in junior high school science education, while also offering practical guidelines for more contextually relevant learning designs aimed at bolstering scientific literacy.

2. METHOD

This study employed a quantitative approach with a quasi-experimental design because the researchers did not fully randomize the subjects but instead utilized existing classes at the school. The design used was a nonequivalent control group design, involving two groups (an experimental class and a control class) that were both given the same pretest and posttest. However, only the experimental class received the innovative learning treatment. The subjects were eighth-grade students at a public junior high school, with 60 students divided into two classes: 30 students in the experimental

class and 30 students in the control class. The experimental and control classes were determined based on considerations of equivalence in initial academic characteristics and classroom conditions that facilitated the implementation of learning, thus ensuring that both classes were sufficiently representative for comparison.

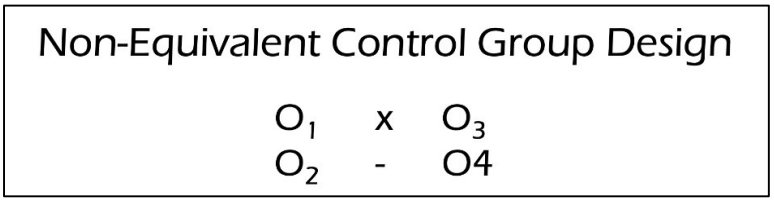

Figure 1. Nonequivalent Control Group Design

The research procedure began with a pretest administered to both classes to obtain an overview of the students' initial abilities in the material studied and their initial scientific literacy levels. After the pretest, the experimental class was given a treatment using the Problem-Based Learning (PBL) model supported by digital media, while the control class followed conventional learning commonly used in schools. In the experimental class, learning began with the presentation of a contextual problem relevant to the material (e.g., a health issue related to the digestive system). Students were then guided to identify the problem, formulate questions, seek information from various sources, discuss findings in groups, develop scientific solutions/explanations, and present their results. Digital media, such as instructional videos and/or interactive simulations, served as the primary support in this process, helping visualize the digestive process and strengthening conceptual understanding. In the control class, learning was conducted through teacher explanations, questions and answers, and practice exercises, with an emphasis on direct delivery of material and reinforcement of concepts. After the entire learning process was completed, both classes were given a posttest to measure science learning outcomes and scientific literacy after the treatment.

The research instrument consisted of two types of tests. First, a multiple-choice science learning outcome test measured conceptual mastery and understanding of the material, encompassing indicators of factual knowledge, conceptual knowledge, and simple application. Second, the science literacy test took the form of contextual descriptive questions that required students to explain scientific phenomena, use concepts to interpret information, and provide scientific reasons for problems related to everyday life. Data obtained from the pretest and posttest were then analyzed quantitatively. Prior to hypothesis testing, prerequisite tests were conducted in the form of a normality test to ensure data distribution was close to normal and a homogeneity test to ensure the variances of both groups were relatively equal. If the prerequisites were met, testing for differences between the experimental and control classes was conducted using an independent sample t-test at a significance level of 0.05 to determine whether there were significant differences in science learning outcomes and science literacy between the two groups after the treatment.

3. RESULTS AND DISCUSSION

Results

This study aims to determine the effect of the implementation of the Problem Based Learning (PBL) model assisted by digital media on students' learning outcomes and scientific literacy in the digestive system material in junior high schools. Data on learning outcomes and scientific literacy were obtained through pretests and posttests in the experimental and control classes. A summary of descriptive statistics is shown in Table 1. Descriptively, the average pretest scores of science learning outcomes in the experimental class (M = 54.20; SD = 8.10) and the control class (M = 53.80; SD = 7.90) were in relatively the same category. The same pattern was also seen in scientific literacy, where the average pretest of the experimental class (M = 51.60; SD = 7.60) was not much different from the control class (M = 51.10; SD = 7.40). After the treatment, the average posttest of the experimental class increased higher than the control class, both in science learning outcomes and scientific literacy. In science learning outcomes, the experimental class achieved an average posttest score of 82.10 (SD = 6.50), while the control class achieved 74.30 (SD = 7.10). In science literacy, the experimental class achieved an average posttest score of 79.40 (SD = 6.90), while the control class achieved 71.20 (SD = 7.20). This indicates that descriptively, students in the experimental class experienced an increased understanding of the concept of the digestive system and better scientific literacy skills after implementing PBL learning assisted by digital media.

Table 1. Descriptive statistics of pretest and posttest scores (n=30 per class)

Variables	Class	Pretest (M ± SD)	Posttest (M ± SD)
Science Learning Outcomes	Experiment	54,20 ± 8,10	82,10 ± 6,50
Science Learning Outcomes	Control	53,80 ± 7,90	74,30 ± 7,10
Scientific Literacy	Experiment	51,60 ± 7,60	79,40 ± 6,90
Scientific Literacy	Control	51,10 ± 7,40	71,20 ± 7,20

To confirm the improvement, the average difference (gain) between the pretest and posttest is shown in Table 2. The results show that the experimental class's gain was greater than that of the control class in both variables, namely science learning outcomes (ΔM = 27.90 vs. 20.50) and science literacy (ΔM = 27.80 vs. 20.10). This pattern confirms that the integration of PBL and digital media is associated with higher improvement than conventional learning.

Table 2. Gain (Difference) of Average Pretest–Posttest Scores

Variables	Class	Gain (Posttest – Pretest)
Science Learning Outcomes	Experiment	27,90
Science Learning Outcomes	Control	20,50
Scientific Literacy	Experiment	27,80
Scientific Literacy	Control	20,10

Before conducting the hypothesis test, a prerequisite test was conducted to ensure the data met the parametric statistical assumptions. The results of the normality test (Shapiro–Wilk) and the homogeneity of variance test (Levene) are shown in Table 3.

The significance value of the normality test for all groups and variables was at $p > 0.05$, indicating that the data were normally distributed. In addition, the homogeneity test results showed $p > 0.05$, so the variances of both classes can be considered homogeneous. Thus, the data met the requirements for the independent sample t-test.

Table 3. Prerequisite Tests (Shapiro–Wilk and Levene) for Posttest Scores

Variables	Normality Test (Shapiro–Wilk) p (Experiment)	p (Control)	Homogeneity Test (Levene) p
Science Learning Outcomes	0,219	0,164	0,412
Scientific Literacy	0,137	0,081	0,528

The results of the independent sample t-test on the post-test scores of science learning outcomes showed a significant value of $p < 0.05$, indicating a significant difference in science learning outcomes between students who learned using PBL assisted by digital media and students who learned using conventional learning. Statistically, the average difference was significant and had a strong effect size (Table 4). Similar findings were also shown in science literacy, where the t-test showed $p < 0.05$, indicating a significant difference in science literacy between the two classes. Descriptively and inferentially, students in the experimental class demonstrated better abilities in explaining the digestive process scientifically, linking concepts to contextual problems, and interpreting science-based information.

Table 4. Results of the Independent Sample T-Test Posttest Score ($\alpha = 0.05$)

Variables	Experimental Mean	Control Mean	t	df	p	Cohen's d
Science Learning Outcomes	82,10	74,30	4,54	58	<0,001	1,17
Scientific Literacy	79,40	71,20	4,52	58	<0,001	1,16

Discussion

The research findings show that the application of the Problem-Based Learning model with the aid of digital media has a positive impact on students' science learning outcomes in the digestive system. These findings demonstrate that learning that begins with contextual problems can encourage students to more actively develop conceptual understanding through investigation and discussion. This aligns with the view that PBL is effective in improving conceptual understanding and higher-order thinking skills in science learning (Arviani et al., 2023; Cantona et al., 2023; Suastra et al., 2019).

The use of digital media in PBL learning also contributes to helping students understand the abstract concept of the digestive system. Visualizing the digestive process through video and interactive media allows students to construct clearer mental representations, thus facilitating conceptual understanding. These findings support multimedia learning theory, which states that combining visual and verbal

representations can enhance student understanding when designed appropriately (Cavanagh & Kiersch, 2023; Çeken & Taşkın, 2022; Noetel et al., 2022). These results also align with previous research that reports that digital media can increase learning engagement and understanding of science concepts (Matovu et al., 2023; Nurhasanah et al., 2025; Zafeer et al., 2025).

In addition to improving learning outcomes, the implementation of PBL with digital media has also been shown to improve students' scientific literacy. Students in the experimental class demonstrated improved ability to explain scientific phenomena related to the digestive system, identify health problems related to the digestive system, and use scientific knowledge to provide simple solutions. These findings align with research suggesting that problem-based learning can strengthen scientific literacy skills because students are directly involved in solving contextual problems (Lubis et al., 2022; Sari et al., 2024; Suhirman & Khotimah, 2020).

Thus, the integration of PBL and digital media creates a learning environment that supports the simultaneous development of learning outcomes and scientific literacy. These results reinforce previous findings and provide additional empirical evidence in the context of junior high school science learning in Indonesia, particularly on the digestive system. However, this study still has limitations in terms of material coverage and number of research subjects, so further research with a broader scope is needed.

4. CONCLUSION

This study indicates that the implementation of the Problem-Based Learning (PBL) model with digital media has a significant positive impact on the quality of science learning, particularly on the digestive system. The result is based on the significant difference in learning outcomes between the experimental and control classes ($p < 0.001$). The class using digital PBL achieved an average posttest score of 82.10, higher than the conventional class, which only achieved 74.30. Students' scientific literacy improved significantly, with an average score of 79.40 in the experimental class compared to 71.20 in the control class. Students improved their ability to explain the digestive process scientifically and relate concepts to contextual problems. Furthermore, the integration of PBL and digital media had a strong effect size (Cohen's $d > 1.1$) on both learning outcomes and scientific literacy. The data demonstrates that this combination is far more effective in improving student competency than conventional learning methods.

As a recommendation, teachers are advised to begin integrating digital media (such as interactive simulations or instructional videos) into problem-based learning syntax to help students visualize abstract biological processes in the digestive system. Considering that this research is limited to digestive system materials, further researchers can test the effectiveness of this digital media-assisted PBL model on other biological or physics materials that have a high level of complexity.

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