



## Effects of Problem-Based Learning on Elementary Students' Scientific Literacy: A Quasi-Experimental Study

<sup>a</sup>Juliana Dadiara, <sup>a\*</sup>Marleny Leasa, <sup>b</sup>John Rafafy Batlolona

<sup>a</sup>Elementary School Teacher Education Study Program; <sup>b</sup>Physics Education Study Program, Faculty of Teacher Training and Education, Pattimura University, Ambon, Indonesia

\*Corresponding Author e-mail: [marlenyleasa3@gmail.com](mailto:marlenyleasa3@gmail.com)

Received: October 2025; Revised: January 2026; Published: January 2026

### Abstract

This study investigated the effect of Problem-Based Learning (PBL) on elementary school students' scientific literacy in ecosystem learning. A quasi-experimental pretest-posttest non-equivalent control group design was employed involving 32 fifth-grade students from two primary schools in Ambon City, Indonesia. The experimental group consisted of 20 students from SD Negeri 76 Ambon, while the control group consisted of 12 students from SD Inpres 45 Ambon. The intervention was implemented over four weeks (eight lessons, 70 minutes each). The experimental group was taught using a structured seven-stage PBL model, whereas the control group received conventional teacher-centered instruction. Scientific literacy was assessed using an eight-item essay test aligned with PISA-oriented indicators, namely explaining scientific phenomena, designing and evaluating scientific investigations, and interpreting data and evidence. The instrument demonstrated acceptable validity ( $r = 0.70$ ) and reliability (Cronbach's  $\alpha = 0.84$ ). Data analysis using an independent samples t-test revealed a statistically significant difference between groups ( $t = -2.692$ ,  $p = 0.012$ ). Students in the PBL group achieved substantially higher posttest scores ( $M = 70.00$ ,  $SD = 8.41$ ) than those in the conventional group ( $M = 54.00$ ,  $SD = 7.96$ ), indicating a meaningful instructional effect. Further analysis showed that PBL particularly strengthened students' abilities to interpret data and construct evidence-based explanations. These findings suggest that PBL is an effective instructional approach for enhancing scientific literacy in elementary ecosystem learning contexts, although conclusions should be limited to similar classroom settings and sample characteristics.

**Keywords:** Scientific Literacy; Problem-Based Learning; Science Learning; Elementary School Students

**How to Cite:** Dadiara, J., Leasa, M., & Batlolona, J. R. (2026). Effects of Problem-Based Learning on Elementary Students' Scientific Literacy: A Quasi-Experimental Study. *Prisma Sains : Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, 14(1), 224–242. <https://doi.org/10.33394/j-ps.v14i1.18074>



<https://doi.org/10.33394/j-ps.v14i1.18074>

Copyright© 2026, Dadiara et al.

This is an open-access article under the [CC-BY](https://creativecommons.org/licenses/by/4.0/) License.



## INTRODUCTION

Science literacy is one of the main competencies that has become a focus of 21st-century learning. Therefore, society needs to keep up with and adapt to rapid advancements in science and technology. It is crucial for the information society to utilize these developments for their future. In a rapidly changing world, education must prioritize teaching young generations to understand and use the latest scientific tools and technologies. Although science literacy has been considered a crucial learning outcome in science education for years, research shows that many societies in developing and developed countries still lack adequate knowledge and skills in science and technology (Fortus et al., 2022). Currently, science plays a dominant and significant role in the lives of individuals and society (Bencze & Carter, 2011). This is evident in everyday issues in public discourse, such as climate change, sustainable development, global pandemics, and other important issues that require direct societal attention. Along with these issues, society is now flooded with information, misinformation, and disinformation that need to be read, interpreted, evaluated, responded to, followed up on, or even ignored. The decisions made can potentially lead to chaos in economic, environmental, or social aspects (Broderick,

2025). Therefore, it is essential for every citizen to have adequate science literacy education to gather knowledge about these issues and, subsequently, engage critically and responsibly in offering scientifically-based solutions when there are social implications (Kolstø, 2006).

Scientific thinking and science literacy are defined as the ability to understand the methods and principles of scientific research. These concepts also involve the application of scientific inquiry methods and principles to reasoning or problem-solving situations and the use of skills involved in generating, testing, and revising theories. Science literacy is a concept introduced in the late 1950s by Paul DeHart to highlight the important role of science in society and emphasize that science education should prepare individuals to engage in human and social issues (Hurd, 1958). In earlier educational practices, science education approaches focused heavily on textbooks, treating science as a collection of information and generalizations to be memorized. The global influence, especially through the 'Space Race' in the 1960s, which showed the United States lagging behind the Soviet Union in launching the first satellite into Earth's orbit, prompted policymakers to invest resources in science education and curriculum development in the US and Europe (Bybee & Fuchs, 2006). A report by Gao et al., (2016) shows an increase in science literacy among Chinese citizens during 2005-2015. According to the latest data released by the Chinese Association for Science and Technology in October 2015, 6.20% of Chinese citizens demonstrated science literacy, with a 4.7% increase compared to 1.50% in 2005. The positions of Shanghai, Beijing, and Tianjin as cities with the highest science literacy in China are not surprising. Interestingly, the science literacy levels in Shanghai and Beijing in 2015 were almost comparable to those in the United States in the late 20th century, around 17.3% in 1999, and higher than the European Union's average in 2005, which was only 13.8%. Meanwhile, Tianjin in 2015 had a science literacy level comparable to that of the United States in 1995, around 12.0%. However, it is essential to note that there are disparities in the development of science literacy across regions. In addition to the mentioned provinces, there are four other provinces, namely Jiangsu, Zhejiang, Guangdong, and Shandong, which showed better performance than the average in the survey. This picture provides evidence that science literacy is crucial for a country's progress.

A student who does not hone literacy and numeracy skills in elementary school will struggle to achieve optimal academic performance, hindering their ability to learn and participate in a broader academic environment (Conica et al., 2023). Science literacy plays a strategic role in equipping students with high-level thinking skills and problem-solving abilities relevant to real-life situations (Lee-Hammond & McConney, 2016). These skills are essential for students to face global challenges such as adapting to climate change, understanding the implications of new technologies, and making decisions based on valid data. This is supported by Udompong & Wongwanich (2014), who state that science literacy is crucial for students to understand technology, economy, health, environment, and modern society. This includes learning critical thinking and using scientific reasoning to discover and respond to social problems. The correlation between science literacy and belief in scientific facts may occur because individuals with science literacy have a better ability to detect flawed reasoning. Thus, they become less susceptible to poor-quality arguments (Stekelenburg, 2026). For example, in Taiwan, science literacy, including dimensions of knowledge, skills, and attitudes, has been a long-term concern from the teacher's perspective (Chang et al., 2009). All these concerns raise questions for science educators about how to create a meaningful science curriculum for all individuals (Tseng et al., 2010). The science education literature indicates that scientific literacy is widely valued and recognized by educators as an important and desirable student learning outcome. However, the meaning of scientific literacy within the context of classroom practice remains a subject of debate. This is due to the inherent complexity of the concept of scientific literacy itself, as well as the diverse interpretations and expectations regarding the learning outcomes students are expected to achieve. In practice, even when teachers possess adequate disciplinary knowledge and strong pedagogical competence, students often continue

to experience difficulties in scientific literacy. This condition suggests that scientific literacy does not depend solely on teachers' ability to deliver content or implement instructional strategies, but is also influenced by other factors, such as how students make sense of scientific concepts, their ability to connect scientific knowledge to everyday life contexts, and the opportunities provided for them to engage in meaningful scientific activities. Therefore, the development of scientific literacy requires a more comprehensive instructional approach that goes beyond the mere transmission of knowledge and emphasizes the strengthening of critical thinking skills, scientific reasoning, and the application of scientific concepts across various contexts. Without a clear understanding and consistent implementation of scientific literacy in classroom practice, the gap between teachers' competencies and students' scientific literacy skills will continue to persist (Smith et al., 2012).

The level of science literacy among students in various countries participating in the Programme for International Student Assessment (PISA) test still needs improvement. Around 72% of students are at levels 1-2, 36% at level 3, and only 1% reach level 4 (OECD, 2019). In Indonesia, around 60% of students are still below level 2 out of six levels (OECD, 2019). Most students begin to show the ability to participate in thinking about science, technology, and related issues. They can only apply basic science knowledge in familiar contexts. The findings of Shahzadi & Nasreen (2020) indicate that most students are at the nominal and functional levels, while the procedural and multidimensional levels remain very low. The study's findings indicate that the science literacy of elementary school students is at a relatively low level (Yuliana et al., 2025). Additionally, Merta et al. (2020) reported that 48 percent of junior high school students demonstrated low to very low levels of scientific literacy. This finding is further reinforced by cross national studies indicating that science literacy levels in the United States remain relatively low, raising substantial concern among educators and policymakers (Cromley, 2009). The common cause of low science literacy skills is the lack of emphasis on the development of science literacy in learning activities (Naresti et al., 2024). Developing science literacy among children is a complex process because children's learning is influenced by several factors, such as educational institutions, games, and deliberate teaching, educators' perceptions, parents, and social and cultural factors (Roy et al., 2025). The low level of science literacy is closely related to how the learning process takes place in the classroom (Ding, 2022). The study's findings indicate that the science literacy of prospective elementary school teachers still needs improvement to align with science education reform (Al Sultan et al., 2021). To improve students' science literacy, elementary school teacher preparation programs must emphasize the importance of solid science education for prospective teachers so that they can provide effective learning (Vieira & Tenreiro-Vieira, 2016; Johansen & Afdal, 2018). Therefore, students with good science literacy will determine their existence in society (Díez-Palomar et al., 2022). Another study reveals that high school teachers have lower scientific reasoning levels compared to active researchers (Synak et al., 2024). The use of less effective strategies results in science literacy not being well-trained. As a result, students cannot connect their knowledge with natural phenomena or problems faced in daily life. This is in line with Suárez-Mesa & Gómez (2024) findings, which show that teacher-directed instruction is the strongest predictor of science literacy.

Meanwhile, scientific literacy is crucial to keep pace with rapid technological advancements (Prihatiningtyas et al., 2025). Therefore, innovative approaches are needed to not only enhance scientific literacy. One such innovative approach that can be adopted is the use of Problem-Based Learning (PBL) strategies. This is because PBL is a constructivist pedagogical approach widely used in science education and is effective in improving academic achievement and 21st-century skills (Belland et al., 2019; Leasa et al., 2023). At the University of California, Los Angeles, many courses combine STEM with PBL to foster collaboration in the classroom, such as utilizing peer learning assistants, additional online resources, and discussion-oriented lecture formats to encourage active learning and problem-solving in

science education (Ramachandran & Rodriguez, 2020). PBL promotes self-motivated learning and synthesis skills, which, when applied in the context of scientific literacy, can equip students with the ability to generate informed opinions about new scientific advancements throughout their lives (Hussa, 2018; Batlolona et al., 2020). A large university in the southeastern region implemented curriculum changes in its biology department. The curriculum was implemented using active learning techniques combined with student collaboration. This was proven to be successful, as at the end of the academic year, the increase in scientific literacy was significantly higher in students in the reformed curriculum ( $p = 0.005$ ), with a two-fold increase in scientific literacy compared to the group in the non-reformed curriculum (Auerbach & Schussler, 2017). Moreover, another study revealed several issues in contemporary education that lead to low scientific literacy among students in Slovakia. The implementation of PBL elements in their teaching was found to have students with sufficient content knowledge but inadequate procedural and epistemic knowledge, making it difficult for them to utilize it in problem-solving activities (Bellová et al., 2017). From the available information, PBL has been proven to improve students' scientific literacy when applied in both science and non-science learning. PBL is recognized as a learning model that supports students in developing various competencies, such as collaboration, communication, critical thinking, and problem-solving skills (Haruehansawasin & Kiattikomol, 2017). According to Haruehansawasin & Kiattikomol (2017), the goal of PBL is to help students develop thinking abilities and problem-solving skills, as well as become independent learners. Nevertheless, most previous studies have focused on secondary and higher education levels, employed general measures of learning outcomes or higher order thinking skills, and assessed scientific literacy in a global manner without examining specific scientific literacy indicators. Furthermore, research investigating the impact of PBL on elementary school students' scientific literacy, particularly studies that use scientific literacy indicators aligned with the PISA framework and are applied to the context of ecosystem topics, remains very limited. This situation indicates a research gap concerning how and to what extent the PBL model influences elementary school students' scientific literacy at the level of specific scientific literacy indicators.

A study by Ali et al. (2025) showed that PBL has an effect size of 0.93, indicating a significant improvement in student learning outcomes. Moderating factors that influence the effectiveness of PBL include education level, geography, assessment methods, and instructional media. PBL is considered a vital pedagogical approach in enhancing students' scientific literacy. Its significant effectiveness and the absence of publication bias support the integration of PBL into the global education system. This study encourages the education community to adopt PBL and emphasizes the importance of teacher training and curriculum updates to enhance students' critical and creative thinking. A bibliometric analysis was conducted to identify research trends related to PBL in elementary schools. The results of Puspita et al. (2023) informed that 98 articles from publications between 2017 and 2021 were analyzed. The year 2020 recorded the highest number of publications, likely related to the impact of the COVID-19 pandemic on teaching methods. Key themes identified included critical thinking, learning outcomes, and science process skills. Furthermore, a study by Akcay & Benek (2024) conducted a systematic review of 133 studies (37 articles, 96 theses) on PBL in science education in Turkey from 2000 to 2023. PBL had a positive impact on 34 skills, including critical thinking and problem-solving. Although PBL has been proven effective in enhancing skills such as critical thinking and collaborative learning, its impact on some other skills, including scientific literacy among students, remains limited. Therefore, this study aimed to explore this issue.

One topic that remains challenging for elementary school students is ecosystems (Gal et al., 2020; Ayotte-Beaudet et al., 2023). Although ecosystems are an essential topic in elementary school curricula in many countries, students still struggle to understand the types of relationships built between organisms and their abiotic environment (Hokayem & Gotwals,

2016; Asilevi et al., 2025). This topic is one of the materials used in the PISA test as a context to measure students' scientific literacy. This is presented in the PISA 2025 Science Framework, which emphasizes scientific competencies in environmental science, including human interactions with the Earth's system, biodiversity, environmental change, and evidence-based actions to maintain sustainability (OECD, 2023). Therefore, ecosystems are crucial for students to master to enhance their scientific literacy. Ecosystems in elementary schools are a highly relevant topic to be taught using the PBL model. This is because ecosystem materials allow students to understand complex interactions between organisms and their environment (Elomaa et al., 2024). When analyzing the impact of changes in an ecosystem, it is not enough to look at individual organisms. Instead, the impact on population interaction levels, such as predator-prey relationships, must be considered. This often involves analyzing indirect and cyclical impacts, such as feedback loops, mediated consequences, and potential side effects. These impacts are often only visible gradually (Mambrey et al., 2022). The application of PBL encourages students to explore problems related to ecosystems, such as food chain balance, environmental change impacts, and biodiversity conservation, thereby enhancing scientific literacy in a real context (Nguyen et al., 2024). This is because PBL not only encourages students to memorize principles or information but also to study the interactions between individuals and their environment (Rathleff et al., 2025). Ecosystem materials also provide opportunities for students to develop critical thinking and collaboration skills in seeking solutions to authentic environmental problems. By studying ecosystems through PBL, students can more easily connect scientific concepts with real-life applications, a key aspect of scientific literacy (Burrow, 2018). This study not only compares scientific literacy outcomes between PBL and conventional instruction, but also maps the impact of each stage of PBL on PISA oriented scientific literacy indicators, including explaining scientific phenomena, interpreting data and evidence, and evaluating scientific issues, within the context of ecosystem learning in elementary schools. Therefore, this study offers new insights into the pedagogical mechanisms of PBL in shaping students' scientific literacy from the elementary education level, rather than merely demonstrating its general effectiveness. In conclusion, the delivery of ecosystem materials in elementary schools is a topic highly related to the use of the PBL model. The purpose of this study is to determine the differences in students' scientific literacy abilities using the PBL model and those using conventional learning models.

## METHOD

### Research Design

This study is a quasi-experimental study aimed at investigating the effect of the PBL model on students' scientific literacy. In this study, the researcher used a pretest-posttest non-equivalent control group design, which involved two groups, namely the experimental group and the control group. At the beginning of the study, the researcher administered a pre-test to both groups to measure the students' initial abilities. Then, the experimental group was treated using the problem-based learning model, while the control group used a conventional approach. The research design follows that of Capili & Anastasi (2025), as shown in Table 1.

**Table 1.** Pretest–Posttest Control Group Research Design

Group	Pretest	Treatment	Posttest
Experimental	O <sub>1</sub>	X	O <sub>2</sub>
Control	O <sub>3</sub>	-	O <sub>4</sub>

This is in line with research conducted Capili & Anastasi (2025) that quasi-experimental design is a research method similar to true experiments, but it does not involve random assignment to control and experimental groups. This design typically involves two groups, namely the group that receives intervention and the control group that does not receive intervention, to compare the results. The PBL used in the experimental group is a learning

approach that involves students in a real and relevant project to everyday life. Through this approach, students are expected to improve their scientific literacy. Meanwhile, the control group was taught using a conventional instructional approach characterized by teacher centered instruction. Learning activities in the control class primarily involved lectures, textbook based explanations, and question and answer sessions guided by the teacher. Students received information directly from the teacher, followed by individual exercises based on textbook questions, with limited opportunities for collaborative discussion, independent inquiry, or problem exploration. Unlike the PBL model applied in the experimental group, the conventional approach did not require students to identify problems, formulate hypotheses, conduct investigations, or synthesize information independently. Through this approach, students are expected to improve their scientific literacy.

After the treatment was given, the researcher administered a post-test to both groups to measure the students' abilities after the treatment. Thus, this study can measure the consequences of the treatment given to the experimental and control groups. The researcher hopes that this study can contribute to the development of innovative and effective learning approaches to improve student learning outcomes. In addition, this study is also expected to provide valuable information for teachers and educators in choosing the right learning approach to improve student learning outcomes. In conducting the research, the researcher carried out several stages, namely the pre-research stage, the implementation stage, and the data analysis stage, to obtain valid and reliable results. Valid and reliable data can increase confidence in the research results and make the research results more reliable (Oluwatayo, 2012; Karnia, 2024).

### **Research Sample**

This study was conducted at two primary education institutions in Ambon City, namely SD Negeri 76 Ambon, which consisted of 20 students, and SD Inpres 45 Ambon, which consisted of 12 students, with the aim of investigating the effectiveness of applying experimental learning methods on student learning outcomes. The selection of these two schools was based on the consideration that they have relatively homogeneous characteristics in terms of educational facilities and infrastructure, as well as their locations being not too far apart, thus minimizing external variables that could affect the validity of the research results. The sampling process in this study used a random sampling method, where each class had an equal opportunity to be selected as a research sample. This is in line with Ahmed (2024), who states that simple random sampling is an effective method to ensure that every member of the population has an equal chance of being selected. The process involved creating a complete list of the population, determining the sample size, and conducting random selection using a random number generator or drawing. This method reduces selection bias but can be logistically challenging, especially for large or dispersed populations. Based on the results of the drawing, grade 5 at SD Negeri 76 Ambon, consisting of 20 students, was selected as the experimental class that would apply the experimental learning method, while grade 5 at SD Inpres 45 Ambon, consisting of 12 students, was selected as the control class that would use the conventional learning method. Thus, this study compares the learning outcomes of students between the class using the experimental learning method at SD Negeri 76 Ambon and the class using the conventional learning method at SD Inpres 45 Ambon, so that a clearer picture can be obtained about the effectiveness of applying experimental learning methods in improving student learning outcomes.

### **Instrument Development**

The learning instrument package developed in this study consisted of teaching modules, student worksheets, and 8 essay test questions that were designed to meet the predetermined science literacy indicators. The science literacy indicators used in this study referred to the framework developed by OECD (2019), which comprised three main aspects: (1) explaining

phenomena scientifically, (2) designing and evaluating scientific investigations, and (3) interpreting data and evidence scientifically. To ensure that the developed learning instrument package met the expected quality standards, validation and reliability tests were conducted. The validation test results indicate that the average validity coefficient of the learning instrument package is 0.56282, which exceeds the  $r$  table value of 0.413. Additionally, the reliability test results also showed that the Cronbach's Alpha value was 0.625, which was greater than the reference value of 0.60. Therefore, it can be concluded that the learning instrument package developed in this study met the expected quality standards and can be used to measure students' science literacy. The categories of student scientific literacy assessment used in this study are presented in Table 2.

**Table 2.** Categories of Students' Scientific Literacy Profiles

Literacy Level	Description
80-100	Very high
66-79	High
56-65	Medium
50-55	Low
0-39	Very Low

Sources: (Rusilowati & Susilaningsih, 2024)

### Data Analysis Techniques

Based on the results of the prerequisite test of the scientific literacy instrument, the validity and reliability values were obtained at 0.70 and 0.84, respectively. The conclusion is that the validity and reliability criteria of the scientific literacy test instrument are appropriate. The data analysis technique employed in this study was the independent samples  $t$  test, which aimed to determine whether there was a significant difference between the experimental class and the control class. Prior to conducting the independent samples  $t$  test, prerequisite tests were carried out to ensure that the data met the required assumptions. These prerequisite tests included a normality test, which was conducted to determine whether the data followed a normal distribution. The normality test is essential because the independent samples  $t$  test assumes that the data are drawn from populations with a normal distribution. The Shapiro Wilk test was used for the normality test due to the small sample size, with  $n$  less than 50. In addition, a homogeneity test was performed to determine whether the data were derived from homogeneous populations. The homogeneity test is important because the independent samples  $t$  test also assumes that the data originate from populations with homogeneous variances. By conducting these prerequisite tests, it was expected that the data would satisfy the necessary assumptions for performing the independent samples  $t$  test, thereby allowing the results of the data analysis to be interpreted more accurately and reliably.

### Implementation of PBL in the Experimental School

The implementation of PBL in this experimental school used a teaching material with seven stages, as proposed by Bokonjic et al. (2009). A brief summary of the steps used during the implementation can be seen in Table 3.

**Table 3.** PBL Steps Used in the Study

Stages	Activities
Clarifying terms	Students are asked to draw a table on the blackboard with four columns: Facts in the text, Problems, Hypotheses about causes and effects, and Learning objectives. Then, a text with a problem to be identified and solved is introduced to the students, and unfamiliar terminology is explained and clarified.

<b>Stages</b>	<b>Activities</b>
Defining the problem	Students conduct a group discussion to identify the problem and determine methods to find a solution. The identified problem is then written in the "problem" column on the blackboard.
Brainstorming	Students conduct another group discussion to generate different hypothetical ideas to explain the problem. All students are encouraged to speak, and all ideas are considered valuable and recorded.
Hypothesis	Students review the second and third steps, and provide possible explanations for the problem. Finally, a structured hypothesis is selected and written in the "hypotheses about causes and effects" column.
Learning objectives	Students must agree on the learning objectives that can be achieved and understood for the task. These learning objectives will be the knowledge that students need to acquire before they can continue working with the hypothesis.
Searching for information	Students search for information individually with an emphasis on the shared learning objectives. This will provide students with a deeper understanding of the problem they are working on.
Synthesis	Students share their individual findings with other group members. With this new information, they analyze the stated problem and, hopefully, they can understand and find a solution to the identified problem.

The intervention was conducted over a period of four weeks, consisting of eight science lessons, with each lesson lasting 70 minutes. Both the experimental group and the control group received the same total instructional time to ensure classroom time equivalence between groups. The intervention focused on ecosystem topics aligned with the elementary science curriculum, including food chains and food webs, roles of producers, consumers, and decomposers, interactions between biotic and abiotic components, and the impact of environmental changes on ecosystems. Prior to the implementation, the teacher assigned to the experimental group received training on the PBL model. The training focused on understanding the theoretical foundations of PBL, familiarization with the seven PBL stages used in this study, classroom management strategies, and alignment of learning activities with scientific literacy indicators. To ensure implementation fidelity, the researchers monitored the teaching process using an observation checklist based on the PBL stages, and regular discussions were conducted with the teacher to reflect on lesson implementation and address potential challenges. In the experimental group, learning activities were carried out following the seven stages of Problem Based Learning, beginning with problem clarification and problem definition, followed by brainstorming, hypothesis formulation, identification of learning objectives, information searching, and synthesis. Students worked collaboratively in small groups to analyze ecosystem related problems presented in contextual scenarios and were encouraged to observe, investigate, discuss, and communicate their findings. In contrast, the control group was taught using a conventional teacher centered instructional approach. The teacher delivered ecosystem content through lectures and textbook based explanations, followed by guided question and answer sessions and individual written exercises. Although the same ecosystem topics were covered, students in the control group were not engaged in structured problem identification, hypothesis formulation, investigation activities, or collaborative problem solving. By ensuring equivalent instructional time, identical learning objectives, and consistent topic coverage across both groups, any observed differences in students' scientific literacy outcomes can be attributed to the differences in instructional approaches rather than variations in content exposure or instructional duration.

## RESULTS AND DISCUSSION

The data obtained in this study were the students' scientific literacy ability data, which was measured using a description test. The described data were the results from the pretest and

posttest in the experimental class and control class. The research data obtained from the experimental class and control class were classified using the international scale of 0-1000 used by PISA to measure students', as shown in Table 4.

**Table 4.** Distribution of Students' Scientific Literacy Levels in Pretest and Posttest

Group	Test	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Control Class	Pretest	6	1	1	1	0	3
Experimental Class	Pretest	5	5	0	5	3	2
Control Class	Posttest	4	1	1	2	2	2
Experimental Class	Posttest	0	2	2	2	5	9

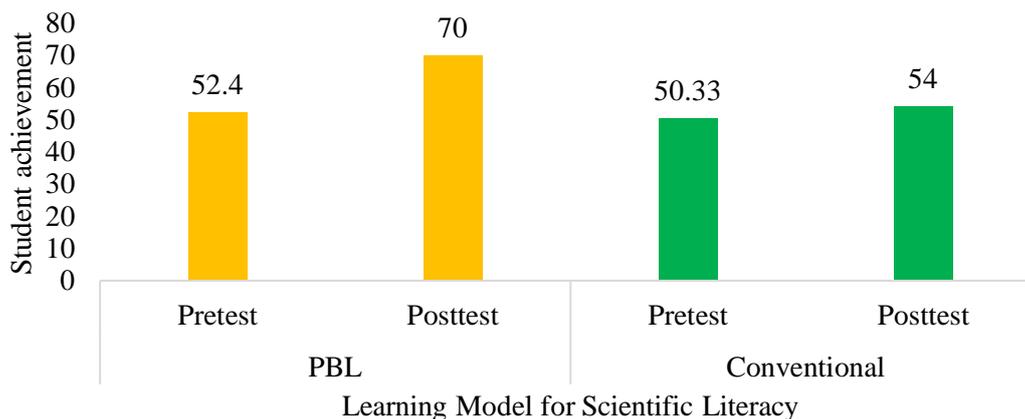
Table 4 shows that on the pretest, which is at level 1 of science literacy, there were 5 students in the experimental class and 6 students in the control class. For level 2, there were 5 students in the experimental class and 1 student in the control class. At level 3, there were no students in the experimental class and 1 student in the control class. At level 4, there were 5 students in the experimental class and 1 student in the control class. For level 5, there were 3 students in the experimental class and no students in the control class. At level 6, there were 2 students in the experimental class and 3 students in the control class. On the posttest, the results were as follows: at level 1, there were no students in the experimental class and 4 students in the control class. For level 2, there were 2 students in the experimental class and 1 student in the control class. At level 3, there were 2 students in the experimental class and 1 student in the control class. At level 4, there were 2 students in both the experimental and control classes. For level 5, there were 5 students in the experimental class and 2 students in the control class. At level 6, there was an increase to 9 students in the experimental class, while the control class decreased to 2 students. This shows that descriptively, there is a difference in science literacy scores between students who learn with the PBL model and those who learn with the conventional model. Furthermore, inferential statistical analysis was conducted on the pretest and posttest data for both classes, which can be seen in Table 5.

**Table 5.** Summary of the Independent Sample t-Test Results

Test	Posttest (PBL Group)	Posttest (Conventional Group)
Normality (Shapiro-Wilk)	0.834	0.680
Homogeneity (Levene Test)		0.372
df		30
$t_{\text{calculated}}$		-2.692
Sig (2tailed)		0.012

Table 5 shows the results of the normality test for the pretest and posttest data, which indicates that the data is normally distributed since sig. > 0.05. Furthermore, the homogeneity test reveals that both classes have homogeneous variances or no significant difference in variances because the sig. value > 0.05. The Independent Sample t-test results show that the Sig. (2-tailed) value (0.012) < 0.05 falls in the acceptance region of  $H_a$  and rejection of  $H_o$ . This means that there is a significant difference in scientific literacy abilities between the experimental class students and the control class students. Therefore, there is a difference in scientific literacy abilities between students who learn using the PBL model and those who learn using the conventional model. Posttest was conducted after both classes were given treatment. The average posttest scores for both classes were 54.00 for the control class and 70.00 for the experimental class. Based on the pretest and posttest scores, it can be seen that before treatment, the experimental class had an average score that was not significantly different from the control class. However, after treatment, the experimental class had a higher

average score compared to the control class. From these results, it can be seen that there is a difference in the improvement of students' scientific literacy in the experimental class.

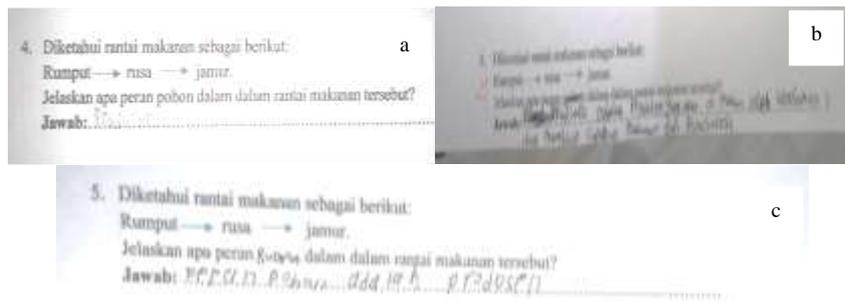


**Figure 1.** Description of Students' Achievement in the Scientific Literacy Test

Students who received treatment using the PBL model showed better improvement in scientific literacy abilities compared to students who only received treatment using the conventional model. This is because learning using the PBL model encourages students to think independently in solving problems, actively engage in the learning process, and connect science with real-life contexts, enabling students to explain, design, and interpret scientific phenomena. This is supported by Uluçinar (2023), who states that PBL is a learning approach that uses real-world problems as a context for students to think critically and develop problem-solving skills to acquire essential knowledge and concepts from learning materials. Additionally, Cong & Ironsi (2025) also state that PBL can activate students in the learning process and improve their thinking skills, enabling students' scientific literacy to develop naturally during the learning process. PBL has great potential to improve learning outcomes and students' scientific literacy (Orhan, 2025). Funa & Prudente (2021) also mention that the PBL model can make students more enthusiastic about learning because they can collaborate in solving problems. Unlike conventional models, which are often one-way and focus on memorization, PBL helps students apply science in problem contexts and develop scientific competencies such as explaining phenomena and interpreting data. Therefore, it can be concluded that PBL is an effective approach to improving students' scientific literacy. These findings are in line with Kasuga et al. (2022), who emphasize that PBL not only significantly improves students' achievement scores compared to traditional teaching methods but also presents greater challenges in achieving higher cognitive abilities. Unlike traditional methods, which tend to maintain stagnant achievement levels, PBL opens up opportunities for students to develop further. Interestingly, PBL also shows that the achievements of male and female students are relatively equal, unlike traditional methods, which often show disparities. Based on these results, this study encourages the consistent implementation of student-centered learning approaches, such as PBL, in science teaching, including Biology, to improve the quality of learning. Other studies also support the idea that student-centered learning enables students to make progress in their understanding of key aspects related to ecosystem concepts. Specifically, they become more aware of the role of humans in the system, although they still experience difficulties in aspects such as identifying species in aquatic ecosystems and distinguishing between biotic and abiotic components (Martín-Gómez et al., 2020).

The difference in students' scientific literacy abilities can also be described through students' answers to pretest and posttest questions. The following are students' answers from the experimental and control classes based on scientific literacy indicators. The first indicator

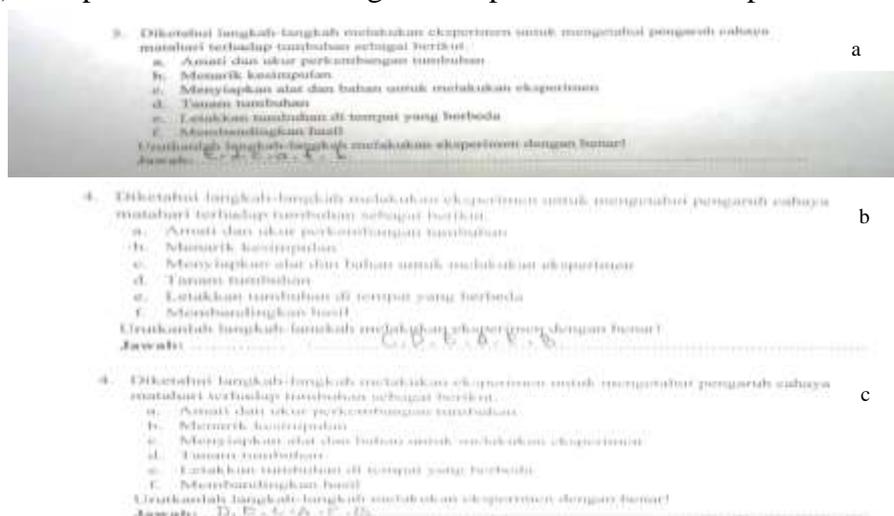
question (explaining phenomena scientifically): "Given a food chain: Grass - Deer - Mushroom. Explain the role of grass in this food chain.



**Figure 2.** Students' answers; a) pretest of experimental class students; b) posttest of experimental class students; c) posttest of control class students

Figure 2 illustrates the pretest responses of students in the experimental class who answered “producer.” The pretest responses of the experimental class were similar to the posttest responses of the control class, which also stated that “the role of grass is as a producer.” By providing only the term “producer,” students merely identified the role of grass without explaining its function. This indicates that students had not yet developed the ability to explain phenomena scientifically, which is an essential component of scientific literacy. This condition can be attributed to students’ limited understanding, as they often rely on memorization without deep conceptual comprehension, as well as to the limited opportunities for them to apply and communicate scientific knowledge. Therefore, PBL can support the development of students’ scientific literacy, particularly in explaining scientific phenomena. This is because PBL encourages students to directly observe, investigate information, and engage in discussions with peers, enabling them to better understand and explain scientific concepts. This improvement is clearly reflected in the posttest responses of students in the experimental class, who initially were only able to mention the role of grass but later explained it as “The role of grass is as a producer that is consumed by primary consumers and that produces its own food reserves.”

The second indicator of scientific literacy is designing and evaluating investigations scientifically. The question is: "Given the steps to conduct an experiment to determine the effect of sunlight on plants as follows: a) Observe and measure plant growth; b) Draw conclusions; c) Prepare tools and materials for the experiment; d) Place plants in different locations; e) Compare the results. Arrange the steps to conduct the experiment correctly.



**Figure 3.** Students' answers; a) pretest of experimental class students; b) posttest of experimental class students; c) posttest of control class students

Figure 3a shows the pretest answers of students in the experimental class who responded with "e, d, c, a, f, b". The posttest answers of the control class students in Figure 3b show a similar incorrect response of "c, d, e, a, f, b" (Figure 3c). Both responses indicate that students' ability to design and evaluate scientific investigations is limited, as they are unable to determine or plan the steps required to conduct an investigation or experiment. In other words, students are not confident in making decisions about the actions they need to take, which suggests that they lack good scientific literacy skills. This is also due to the lack of understanding of scientific concepts and limited experience in conducting scientific investigations or experiments. After being treated with PBL, the experimental class students answered the question correctly with "d, e, c, a, f, b". This is because PBL encourages students to conduct simple investigations or experiments that help them understand and become familiar with designing investigations or experiments, enabling them to make informed decisions about the actions they need to take. This is an essential aspect of scientific literacy. The question for the third indicator of scientific literacy (Interpreting data and evidence scientifically) is: "Andre conducted an experiment to investigate the effect of water on plant growth. Andre obtained data that showed a small amount of water caused the plant to wither, a sufficient amount of water allowed the plant to grow normally, and an excessive amount of water caused the plant to grow too quickly. What can be concluded from this data?."

9. Hasil pengamatan oleh Dina memperoleh data sebagai berikut:

Hewan di lokasi yang banyak tumbuhan	Hewan di lokasi yang tidak memiliki tumbuhan
Burung	Cicak
Kupu-kupu	
Belalang	

Apa yang dapat disimpulkan dari data tersebut?  
Jawab: ..burung...cicak.....

**Figure 4.** Posttest answers of control class students

9. Hasil pengamatan oleh Dina memperoleh data sebagai berikut:

Hewan di lokasi yang banyak tumbuhan	Hewan di lokasi yang tidak memiliki tumbuhan
Burung	Cicak
Kupu-kupu	
Belalang	

Apa yang dapat disimpulkan dari data tersebut?  
Jawab: di lokasi yang banyak tumbuhan pasti banyak hewan.....

**Figure 5.** Posttest answers of experimental class students

Figure 4 presents the posttest response of a student from the control class who answered "bird, lizard." This response indicates that the student has not yet developed adequate scientific literacy skills, particularly in the ability to interpret data and evidence scientifically. Rather than drawing a conclusion based on the experimental data provided, the student merely listed organisms, suggesting a surface-level understanding of the task. This reflects limitations in critical thinking, insufficient conceptual understanding of ecological relationships, and a lack of experience in analyzing data to generate evidence-based conclusions. Such responses are commonly associated with teacher-centered instructional approaches that emphasize factual recall over data interpretation and reasoning. In contrast, the posttest response of a student from the experimental class shown in Figure 5, stating that "in areas with many plants, there are definitely many animals," demonstrates a more advanced level of scientific literacy. This response indicates the student's ability to interpret the data presented, recognize patterns, and infer relationships between biotic components within an ecosystem. The student was able to synthesize information from the investigation and draw a meaningful conclusion supported by evidence, which reflects higher-order thinking and scientific reasoning skills. This difference can be attributed to the implementation of PBL, which provides students with repeated opportunities to engage in data collection, analysis, and interpretation during the learning process. Through collaborative discussions, investigation of real-world problems, and

reflection on findings, students in the PBL group became more accustomed to using evidence to support their conclusions. Consequently, PBL facilitates the development of critical thinking and reasoning skills, enabling students to connect data with relevant scientific concepts. Consistent exposure to problem-based and contextual learning environments helps students move beyond simple identification of facts toward deeper understanding and evidence-based explanation, which are essential components of scientific literacy (Batlolona & Souisa, 2020; Leasa et al., 2024).

Despite the positive and statistically significant findings regarding the effectiveness of PBL in enhancing students' scientific literacy, several limitations of this study should be carefully considered when interpreting the results. First, the relatively small sample size restricts the extent to which the findings can be generalized to broader populations of elementary school students. Although the sample was sufficient to detect significant differences, larger samples would provide stronger statistical power and increase the robustness of the conclusions. Second, the use of a quasi-experimental design without random assignment at the individual student level may have introduced selection bias. While pretest results indicated comparable baseline abilities between groups, unmeasured individual differences could still have influenced the observed outcomes. Third, the unequal number of students between the experimental and control groups represents another limitation that may have affected the magnitude of the treatment effect. Differences in group size can influence variance estimates and statistical sensitivity, potentially impacting the comparability of results. Fourth, the experimental and control groups were drawn from two different schools, which introduces the possibility of school-level confounding variables. Factors such as school culture, instructional climate, administrative support, teacher experience, and student learning environments may have contributed to differences in outcomes independent of the instructional model (Pamularsih, 2022; Savolainen et al., 2025). Although the schools were selected based on similar characteristics, these contextual factors could not be fully controlled within the scope of this study. Finally, the assessment of scientific literacy relied on essay-based test items aligned with PISA-oriented indicators. While essay questions are well suited to capturing higher-order thinking and scientific reasoning, they inherently involve a degree of subjectivity in scoring. Although the instruments were validated and demonstrated acceptable reliability, variations in interpretation during scoring may still have occurred. The absence of multiple independent raters or inter-rater reliability analysis further limits the objectivity of the assessment results. Future research is therefore recommended to involve larger and more balanced samples, implement randomization at the individual level where feasible, and consider multi-site designs with statistical controls for school-level effects. Additionally, the use of detailed scoring rubrics, multiple raters, and inter-rater reliability analysis would strengthen the credibility of essay-based assessments. Addressing these limitations will contribute to a more comprehensive understanding of the impact of PBL on students' scientific literacy and enhance the methodological rigor of future studies in this area.

## CONCLUSION

This quasi-experimental study demonstrates that the implementation of PBL leads to a statistically significant improvement in elementary school students' scientific literacy compared to conventional instruction. Empirical evidence from the independent samples t test reveals a significant difference between the experimental and control groups, with a Sig. value of 0.012, thereby confirming the effectiveness of the intervention. Descriptive analysis further shows that students in the experimental group experienced a substantial increase in mean scientific literacy scores, rising from 52.40 on the pretest to 70.00 on the posttest. In contrast, students in the control group exhibited only a modest improvement, with mean scores increasing from 50.33 to 54.00. The observed improvement in the experimental group was not limited to overall scores but was consistently evident across PISA-oriented scientific literacy

indicators, including explaining scientific phenomena, designing and evaluating scientific investigations, and interpreting data and evidence scientifically. These results indicate that structured engagement in PBL activities provides students with meaningful opportunities to analyze problems, construct explanations, and use evidence to support conclusions. Through repeated exposure to problem identification, investigation, and collaborative discussion, students were able to develop higher-order reasoning skills and apply scientific knowledge more effectively within the context of ecosystem learning. From a practical standpoint, these findings suggest that PBL can function as a viable and effective instructional alternative for elementary science classrooms aiming to strengthen students' scientific literacy. However, its successful implementation requires sufficient instructional time, well-prepared teachers, and alignment between learning activities, curricular objectives, and assessment indicators. When these conditions are met, PBL has the potential to move students beyond rote memorization toward deeper conceptual understanding and evidence-based scientific reasoning.

## RECOMMENDATION

Based on the findings of this study, several recommendations are proposed for both educational practice and future research. In terms of classroom implementation, teachers are encouraged to adopt PBL as an instructional approach to promote students' scientific literacy, particularly by emphasizing core competencies such as data interpretation, investigation design, and evidence-based reasoning in science lessons. To ensure effective implementation, schools and educational stakeholders should provide systematic support through targeted teacher training programs, the availability of appropriate instructional resources, and structured pedagogical guidance that helps maintain fidelity to each stage of the PBL process. Such support is essential to ensure that PBL is implemented as an inquiry-oriented and student-centered approach rather than being reduced to surface-level problem-solving activities. From a research perspective, future studies are recommended to replicate this investigation using larger and more balanced sample sizes in order to enhance the generalizability and robustness of the findings. Employing random assignment at the individual student level, where feasible, and implementing multi-school or multi-site research designs are also suggested to better control for contextual variables at the school level. In addition, longitudinal studies examining the long-term effects of PBL on the retention and transfer of scientific literacy skills would provide valuable insights into the sustainability of learning gains beyond short-term interventions. Future research should also incorporate systematic fidelity measures to assess the consistency and quality of PBL implementation across classrooms, as well as employ multiple raters and inter-rater reliability analysis when using essay-based assessments to minimize scoring subjectivity. Collectively, these research directions will contribute to a more rigorous and comprehensive understanding of the role of PBL in improving elementary students' scientific literacy and informing evidence-based instructional practices.

## FUNDING INFORMATION

This research received no external funding.

## AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Juliana Dadiara	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓
Marleny Leasa		✓				✓		✓	✓	✓	✓	✓		✓
John Rafafy Batlolona	✓		✓	✓			✓		✓	✓	✓		✓	✓

C : Conceptualization

M : Methodology

So : Software

I : Investigation

R : Resources

D : Data Curation

Vi : Visualization

Su : Supervision

P : Project administration

Va : Validation  
Fo : Formal analysis

O : Writing - Original Draft  
E : Writing - Review & Editing

Fu : Funding acquisition

### CONFLICT OF INTEREST STATEMENT

The authors state that they have no conflict of interest related to the research, authorship, or publication of this article.

### INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

### REFERENCES

- Ahmed, S. K. (2024). How to choose a sampling technique and determine sample size for research: A simplified guide for researchers. *Oral Oncology Reports*, *12*, 1–7. <https://doi.org/10.1016/j.oor.2024.100662>
- Akcay, B., & Benek, İ. (2024). Problem-based learning in Türkiye: a systematic literature review of research in science education. *Education Sciences*, *14*(3), 1–26. <https://doi.org/10.3390/educsci14030330>
- Al Sultan, A., Henson, H., & Lickteig, D. (2021). Assessing preservice elementary teachers' conceptual understanding of scientific literacy. *Teaching and Teacher Education*, *102*, 1–10. <https://doi.org/10.1016/j.tate.2021.103327>
- Ali, L. U., Suranto, Indrowati, M., & Suhirman. (2025). A meta-analysis of the effectiveness of problem-based learning on science literacy. *Towards Resilient Societies: The Synergy of Religion, Education, Health, Science, and Technology*, 273–278. <https://doi.org/10.1201/9781003645542-44>
- Asilevi, M. N., Kärkkäinen, S., Kang, J., Sormunen, K., & Havu-nuutinen, S. (2025). Primary school students' experiences of science learning content and support provided during guided inquiry-based science fieldwork. *LUMAT: International Journal on Math, Science and Technology Education*, *13*(1), 1–25. <https://doi.org/10.31129/LUMAT.13.1.2612>
- Auerbach, A. J., & Schussler, E. E. (2017). Curriculum alignment with vision and change improves student scientific literacy. *CBE Life Sciences Education*, *16*(2), 1–9. <https://doi.org/10.1187/cbe.16-04-0160>
- Ayotte-Beaudet, J. P., Chastenay, P., Beaudry, M. C., L'Heureux, K., Giamellaro, M., Smith, J., Desjarlais, E., & Paquette, A. (2023). Exploring the impacts of contextualised outdoor science education on learning: the case of primary school students learning about ecosystem relationships. *Journal of Biological Education*, *57*(2), 277–294. <https://doi.org/10.1080/00219266.2021.1909634>
- Batlolona, J. R., Diantoro, M., Wartono, & Leasa, M. (2020). Students' mental models of solid elasticity: Mixed method study. *Journal of Turkish Science Education*, *17*(2), 200–210. <https://doi.org/10.36681/tused.2020.21>
- Batlolona, J. R., & Souisa, H. F. (2020). Problem based learning: Students' mental models on water conductivity concept. *International Journal of Evaluation and Research in Education*, *9*(2), 269–277. <https://doi.org/10.11591/ijere.v9i2.20468>
- Belland, B. R., Gu, J., Kim, N. J., Jaden Turner, D., & Mark Weiss, D. (2019). Exploring epistemological approaches and beliefs of middle school students in problem-based learning. *Journal of Educational Research*, *112*(6), 643–655. <https://doi.org/10.1080/00220671.2019.1650701>
- Bellová, R., Melicherčíková, D., Tomčík, P., Bellová, R., Melicherčíková, D., & Tomčík, P. (2017). Possible reasons for low scientific literacy of Slovak students in some natural science subjects in some natural science subjects. *Research in Science & Technological Education*, *36*(2), 1–17. <https://doi.org/10.1080/02635143.2017.1367656>
- Bencze, L., & Carter, L. (2011). Globalizing students acting for the common good. *Journal of Research in Science Teaching*, *48*(6), 648–669. <https://doi.org/10.1002/tea.20419>
- Bokonjic, D., Mimica, M., Pranjic, N., Filipovic, V., Cosovic, S., Bosse, H.-M., et al. (2009).

- Problem-based learning*. <http://www.bhmed-emanual.org>
- Broderick, N. (2025). Exploring different visions of scientific literacy in Irish primary science education: core issues and future directions. *Irish Educational Studies*, 44(1), 73–93. <https://doi.org/10.1080/03323315.2023.2230191>
- Burrow, A. K. (2018). Teaching introductory ecology with problem-based learning. *The Bulletin of the Ecological Society of America*, 99(1), 137–150. <https://doi.org/10.1002/bes2.1364>
- Bybee, R. W., & Fuchs, B. (2006). Preparing the 21st century workforce: a new reform in science and technology education. *Journal of Research in Science Teaching*, 43(4), 349–352. <https://doi.org/10.1002/tea>
- Capili, B., & Anastasi, J. K. (2025). An introduction to the quasi-experimental design (nonrandomized design). *AJN The American Journal of Nursing*, 124(11), 50–52. <https://doi.org/10.1097/01.NAJ.0001081740.74815.20.An>
- Chang, C. Y., Chang, Y. H., & Yang, F. Y. (2009). Exploring secondary science teachers' perceptions on the goals of earth science education in Taiwan. *International Journal of Science Education*, 31(17), 2315–2334. <https://doi.org/10.1080/09500690802314868>
- Cong, L., & Ironsi, C. S. (2025). Integrating mobile learning and problem-based learning in improving students action competence in problem-solving and critical thinking skills. *Humanities and Social Sciences Communications*, 12, 1–11. <https://doi.org/10.1057/s41599-025-05397-4>
- Conica, M., Nixon, E., & Quigley, J. (2023). Domain-specific and cross-domain effects of the home literacy and numeracy environment at 3 years on children ' s academic competencies at 5 and 9 years. *Developmental Psychology*, 59(6), 1045–1058. <https://doi.org/10.1037/dev0001515>
- Cromley, J. G. (2009). Reading achievement and science proficiency: International comparisons from the programme on international student assessment. In *Reading Psychology* (Vol. 30, Issue 2). <https://doi.org/10.1080/02702710802274903>
- Díez-Palomar, J., Font Palomar, M., Aubert, A., & Garcia-Yeste, C. (2022). Dialogic scientific gatherings: the promotion of scientific literacy among children. *SAGE Open*, 12(4), 690–696. <https://doi.org/10.1177/21582440221121783>
- Ding, C. (2022). Examining the context of better science literacy outcomes among U.S. schools using visual analytics: A machine learning approach. *International Journal of Educational Research Open*, 3, 1–11. <https://doi.org/10.1016/j.ijedro.2022.100191>
- Elomaa, M., Eskelä-Haapanen, S., Pakarinen, E., Halttunen, L., & Lerkkanen, M. K. (2024). Elementary school principals' work from the ecological systems perspective: Evidence from Finland. *Educational Management Administration and Leadership*, 52(5), 1231–1251. <https://doi.org/10.1177/17411432221125999>
- Fortus, D., Lin, J., Neumann, K., & Sadler, T. D. (2022). The role of affect in science literacy for all. *International Journal of Science Education*, 44(4), 535–555. <https://doi.org/10.1080/09500693.2022.2036384>
- Funa, A. A., & Prudente, M. S. (2021). Effectiveness of problem-based learning on secondary students' achievement in science: A meta-analysis. *International Journal of Instruction*, 14(4), 69–84. <https://doi.org/10.29333/iji.2021.1445a>
- Gal, A., Gan, D., & Ben Zvi – Assaraf, O. (2020). Can elementary school students understand the complexity of the lesser kestrel's ecological system? *Interdisciplinary Journal of Environmental and Science Education*, 17(1), 1–19. <https://doi.org/10.29333/ijese/9152>
- Gao, H., He, W., Zhang, C., & Ren, L. (2016). Building scientific literacy in China: achievements and prospects. *Science Bulletin*, 61(11), 871–874. <https://doi.org/10.1007/s11434-016-1076-0>
- Haruehansawasin, S., & Kiattikomol, P. (2017). Scaffolding in problem-based learning for low- achieving learners. *The Journal of Educational Research*, 0(0), 1–8.

- <https://doi.org/10.1080/00220671.2017.1287045>
- Hokayem, H., & Gotwals, A. W. (2016). Early elementary students' understanding of complex ecosystems: a learning progression approach. *Journal of Research in Science Teaching*, 53(10), 1–22. <https://doi.org/10.1002/tea.21336>
- Hurd, P. D. (1958). Science literacy: its meaning for American Schools. *Educational Leadership*, 16(1), 13–16.
- Hussa, E. A. (2018). Can I still eat it? Using problem-based learning to test the 5-second rule and promote scientific literacy. *FEMS Microbiology Letters*, 365(21), 4–6. <https://doi.org/10.1093/femsle/fny246>
- Johansen, G., & Afdal, H. W. (2018). Comparing and discussing positions on scientific literacy in teacher education and lower secondary school curricula. *International Journal of Learning, Teaching and Educational Research*, 17(2), 99–126. <https://doi.org/10.26803/ijlter.17.2.7>
- Karnia, R. (2024). Importance of reliability and validity in research. *Psychology and Behavioral Sciences*, 13(6), 137–141. <https://doi.org/10.11648/j.pbs.20241306.11>
- Kasuga, W., Maro, W., & Pangani, I. (2022). Effect of problem-based learning on developing science process skills and learning achievement on the topic of safety in our environment. *Journal of Turkish Science Education*, 19(3), 872–886. <https://doi.org/10.36681/tused.2022.154>
- Kolstø, S. D. (2006). Patterns in students' argumentation confronted with a risk-focused socio-scientific issue. *International Journal of Science Education*, 28(14), 1689–1716. <https://doi.org/10.1080/09500690600560878>
- Leasa, M., Abednego, A., & Batlolona, J. R. (2023). Problem-based learning (PBL) with reading questioning and answering (RQA) of preservice elementary school teachers. *International Journal of Learning, Teaching and Educational Research*, 22(6), 245–261. <https://doi.org/10.26803/ijlter.22.6.14>
- Leasa, M., Pelamonia, J., Talakua, M., & Rafafy, J. (2024). Emotional literacy of elementary school teachers: a study on science learning with problem-based learning (PBL) and Homogeneity Psycho Cognition (HPC) program. *KnE Social Sciences*, 2024, 432–444. <https://doi.org/10.18502/kss.v9i31.17605>
- Lee-Hammond, L., & McConney, A. (2016). The impact of village-based kindergarten on early literacy, numeracy, and school attendance in Solomon Islands. *European Early Childhood Education Research Journal*, 25(4), 1–26. <https://doi.org/10.1080/1350293X.2016.1155256>
- Mambrey, S., Schreiber, N., & Schmiemann, P. (2022). Young students' reasoning about ecosystems: the role of systems thinking, knowledge, conceptions, and representation. *Research in Science Education*, 52(1), 79–98. <https://doi.org/10.1007/s11165-020-09917-x>
- Martín-Gámez, C., Acebal, M. del C., & Prieto, T. (2020). Developing the concept of 'ecosystem' through inquiry-based learning: a study of pre-service primary teachers. *Journal of Biological Education*, 54(2), 147–161. <https://doi.org/10.1080/00219266.2018.1554596>
- Merta, I. W., Artayasa, I. P., Kusmiyati, K., Lestari, N., & Setiadi, D. (2020). The profile of science literacy and instruction model can increase science literacy capability. *Jurnal Pijar Mipa*, 15(3), 223–228. <https://doi.org/10.29303/jpm.v15i3.1889>
- Naresti, D. A., Suratmi, & Hartono. (2024). Improving elementary school students' science literacy skills through digital picture storybooks. *Jurnal Ilmiah Sekolah Dasar*, 8(4), 634–643. <https://doi.org/10.23887/jisd.v8i4.86894>
- Nguyen, L. T. Van, Cleveland, D., Nguyen, C. T. M., & Joyce, C. (2024). Problem-based learning and the integration of sustainable development goals. *Journal of Work-Applied*

- Management*, 16(2), 218–234. <https://doi.org/10.1108/JWAM-12-2023-0142>
- OECD. (2019). PISA 2018 assessment and analytical framework. In *OECD Publishing*.
- OECD. (2023). *Education at a Glance 2023 OECD INDICATORS*. [https://www.oecd.org/en/publications/education-at-a-glance-2023\\_e13bef63-en.html](https://www.oecd.org/en/publications/education-at-a-glance-2023_e13bef63-en.html)
- Oluwatayo, J. A. (2012). Validity and reliability issues in educational research. *Journal of Educational and Social Research*, 2(2), 391–400. <https://doi.org/10.5901/jesr.2012.v2n2.391>
- Orhan, A. (2025). Investigating the effectiveness of problem based learning on academic achievement in efl classroom: a meta-analysis. *Asia-Pacific Education Researcher*, 34(2), 699–709. <https://doi.org/10.1007/s40299-024-00889-4>
- Pamularsih, N. (2022). The effects of school climate on students' reading achievement. *Social Sciences & Humanities Open*, 6(1), 1–9. <https://doi.org/10.1016/j.ssaho.2022.100375>
- Prihatiningtyas, S., Shofiyah, N., Yunus, S. R., Ma'arif, I. B., & Putra, I. A. (2025). Enhancing science literacy through flipbook-based STEM Qur'an e-modules: a case study in Islamic boarding schools. *Humanities and Social Sciences Communications*, 12(1), 1–12. <https://doi.org/10.1057/s41599-025-05054-w>
- Puspita, A. D., Maryani, I., & Sukma, H. H. (2023). Problem-based science learning in elementary schools: A bibliometric analysis. *Journal of Education and Learning*, 17(2), 285–293. <https://doi.org/10.11591/edulearn.v17i2.20856>
- Ramachandran, R., & Rodriguez, M. C. (2020). Student perspectives on remote learning in a large organic chemistry lecture course. *Journal of Chemical Education*, 97(9), 2565–2572. <https://doi.org/10.1021/acs.jchemed.0c00572>
- Rathleff, C. R., Vergel, J., Ryberg, T., & Kristensen, J. K. (2025). Medical students' evaluation of digital problem-based learning: a mixed-methods systematic review. *BMC Medical Education*, 25, 1–15.
- Roy, G., Sikder, S., & Danaia, L. (2025). Adopting scientific literacy in early years from empirical studies on formal education: a systematic review of the literature. *International Journal of STEM Education*, 1–24. <https://doi.org/10.1186/s40594-025-00547-1>
- Rusilowati, A., & Susilaningsih, E. (2024). Development of multiple-choice test instruments to improve scientific literacy in Madrasah Aliyah (MA). *International Journal of Scientific Research and Management (IJSRM)*, 12(06), 3465–3475. <https://doi.org/10.18535/ijrm/v12i06.e104>
- Savolainen, P., Korhonen, E., Närhi, V., Kärkkäinen, S., & Savolainen, H. (2025). Factors affecting the behavioral climate in elementary school classrooms. *Scandinavian Journal of Educational Research*, 3831, 1–15. <https://doi.org/10.1080/00313831.2025.2554728>
- Shahzadi, I., & Nasreen, A. (2020). Assessing scientific literacy levels among secondary school science students of District Lahore. *Bulletin of Education and Research*, 42(3), 1–21.
- Smith, K. V., Loughran, J., Berry, A., & Dimitrakopoulos, C. (2012). Developing scientific literacy in a primary school. *International Journal of Science Education*, 34(1), 37–41. <https://doi.org/10.1080/09500693.2011.565088>
- Stekelenburg, A. van. (2026). Science literacy and the acceptance of scientific facts. *Current Opinion in Psychology*, 67, 1–5. <https://doi.org/10.1016/j.copsyc.2025.102183>
- Suárez-Mesa, A. M., & Gómez, R. L. (2024). Does teachers' motivation have an impact on students' scientific literacy and motivation? An empirical study in Colombia with data from PISA 2015. *Large-Scale Assessments in Education*, 12(1), 1–28. <https://doi.org/10.1186/s40536-023-00190-8>
- Synak, N., Šabíková, N., & Masaryk, R. (2024). Correlations among high school students' beliefs about conspiracy, authoritarianism, and scientific literacy. *Science and Education*, 33(1), 159–174. <https://doi.org/10.1007/s11191-022-00380-w>
- Tseng, Y. H., Chang, C. Y., Rundgren, S. N. C., & Rundgren, C. J. (2010). Mining concept maps from news stories for measuring civic scientific literacy in media. *Computers and*

- Education*, 55(1), 165–177. <https://doi.org/10.1016/j.compedu.2010.01.002>
- Udompong, L., & Wongwanich, U. (2014). Diagnosis of the scientific literacy characteristics of primary students. *Procedia - Social and Behavioral Sciences*, 116, 5091–5096. <https://doi.org/10.1016/j.sbspro.2014.01.1079>
- Uluçınar, U. (2023). The effect of problem-based learning in science education on academic achievement: a meta-analytical study. *Science Education International*, 34(2), 72–85. <https://doi.org/10.33828/sei.v34.i2.1>
- Vieira, R. M., & Tenreiro-Vieira, C. (2016). Fostering scientific literacy and critical thinking in elementary science education. *International Journal of Science and Mathematics Education*, 14(4), 659–680. <https://doi.org/10.1007/s10763-014-9605-2>
- Yuliana, I., Jatmiko, B., Widodo, W., Suryanti, & Irwanto. (2025). Primary education students' scientific literacy in terms of some variables. *Edelweiss Applied Science and Technology*, 9(1), 1277–1288. <https://doi.org/10.55214/25768484.v9i1.4384>