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Improving Students' Scientific Literacy in Biology Learning Through Problem-Oriented Project-Based Learning (POPBL) Model with Pekerti Worksheet

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ABSTRACT

This study investigates the effectiveness of the Problem-Oriented Project-Based Learning (POPBL) model, combined with the Pekerti Worksheet, in improving science literacy among students at Middle School 2 Alla, Enrekang, South Sulawesi. POPBL offers a project-based learning approach centered on real-world issues, complemented by the Pekerti Worksheet, which includes questions, essential concepts, action plans, and initiatives. The study utilized a quasi-experimental design with pre-tests and post-tests in a non-equivalent control group format. A total of 75 eighth-grade students were divided into three groups, and data were collected through observations and tests. Hypotheses were tested using Analysis of Covariance (ANCOVA). The results indicate that students in the POPBL group utilizing the Pekerti Worksheet demonstrated significantly higher science literacy scores than both the POPBL group without the worksheet and the conventional learning group. Statistical analysis confirmed that the integration of POPBL and the Pekerti Worksheet had a substantial positive impact on science literacy (p = 0.000). These findings support the implementation of the POPBL model with the Pekerti Worksheet as an effective approach to foster the Independent Curriculum in Indonesia's junior high schools, contributing to the enhancement of essential 21st-century skills.

Keywords: Curriculum; KWHLAQ; POPBL Model; Pekerti Worksheet; Scientific Literacy

INTRODUCTION

Enhancing scientific literacy is essential for students to meet the demands of 21st-century skills (Hindun et al., 2024; Kelp et al., 2023; Milda et al., 2022). The capacity to identify problems, acquire new knowledge, understand scientific phenomena, and make informed decisions based on data and scientific and technological principles is referred to as scientific literacy (OECD, 2019). In other words, an individual who is scientifically literate will have the ability to think critically, apply scientific ideas creatively in meaningful ways, and make appropriate, well-rounded decisions about issues that arise in daily life (Drew & Thomas, 2022; Efrat, 2015; Udompong & Wongwanich, 2014). Scientific literacy is crucial to master due to its broad applicability across nearly all fields (Demirel & Caymaz, 2015; Flores, 2018). Additionally, it is important for understanding of science and its applications to people’s lives (Dragoş & Mih, 2015). Therefore, developed countries continuously strive to enhance scientific literacy skills among the younger generation to ensure they are more competitive in the global job market (Dichev & Dicheva, 2017).

Science education, including biology, not only emphasizes understanding concepts but also requires students to apply scientific principles to solve problems related to biology in daily life. However, assessing students' scientific literacy in biology has not been extensively researched. The scientific literacy of Indonesian students remains relatively low. This can be observed through their performance in the Program for International Student Assessment (PISA). Although Indonesia's ranking improved in 2022 compared to the previous year, its score declined. The 2022 PISA results show Indonesia scoring 383 in Scientific literacy. Indonesia is ranked 67th out of 81 countries (OECD, 2023). It shows that Indonesian education still needs to achieve the international standards required by the global market. Low scientific literacy ability of students makes students less responsive to overcoming changes and problems in the surrounding environment (Hasasiyah et al., 2020). It is due to the low curiosity of students, students tend to be more theoretical and have not been able to relate various concepts in science that are the teacher as a facilitator in the formation of literacy students (Ariska & Rosana, 2020; Kamil et al., 2021). An interview with a science teacher at State Junior High School 2 Alla and a scientific literacy test conducted with the students support the above facts. The ninth-grade students scored 56.01% on the scientific literacy test, which is considered low.

There are several innovative approaches that can be used to encourage students to read, think, investigate, and make decisions about specific topics in order to enhance scientific literacy (Kelp et al., 2023), such as implementing the problem-oriented project-based learning (POPBL) model. POPBL, integrating both problem-based learning (PBL) and project-based learning (PjBL), provides a student-centered approach where learners participate in genuine and practical projects that tackle issues relevant to their environment (Qureshi et al., 2014). PBL begins with the introduction of a problem that students must solve through collaboration and critical thinking, utilizing relevant content knowledge. In contrast, PjBL focuses on completing predetermined projects with an emphasis on final outcomes. Meanwhile, POPBL requires students to formulate their own problems before designing projects to address those issues, highlighting the learning process and fostering the development of analytical skills and collaboration among students (Sørvik & Mork, 2015). The fundamental components of POPBL involve a focus on the learner, experiential learning, solving real-world problems, collaboration, and producing concrete outcomes. Through this model, students utilize their knowledge to solve real problems (Rizki & Suprapto, 2024). POPBL is characterized by its learner-centered approach, emphasizing the learning process and project-based problem-solving (Yasin & Rahman, 2011).

Although POPBL provides students with the freedom to explore and solve problems, this method can sometimes be less structured, particularly for students who are not yet accustomed to it and need effective time management skills. This lack of structure can make it challenging for students to complete projects on time. To address this issue, a structured framework is needed to help students organize their project work (Barell, 2016). The Pekerti worksheet is proposed as a solution. Pekerti, an acronym for *pertanyaan* (questions), *konsep esensial* (essential concepts), *rencana dan tindakan* (plans and actions), and *inisiatif* (initiative), is designed to be easy to remember and apply. The Pekerti worksheet is adapted from the KWHLAQ framework (Know, Want, How, Learned, Action, Question), which guides students in carrying out projects and solving real-world problems by reflecting on their learning experience—what they know, what they want to learn, how to plan and execute a project, and what they have gained during the learning process. The implementation of this strategy is valuable for developing scientific concepts and practical applications in schools (Anindhita et al., 2022; Mihardi, 2013; Zouhor et al., 2016).

LITERATURE REVIEW

Scientific Literacy

Scientific literacy, as one of the key competencies in the Programme for International Student Assessment (PISA) framework, is defined as the ability to understand and apply scientific knowledge broadly, enabling individuals to use this knowledge to achieve broader goals (OECD, 2019). Science literacy is essential to develop not only in science classes but also in non-science subjects. It should not be overlooked and must continuously be explored with students, as it helps them make informed decisions (Gu et al., 2019), solve both individual and global problems (Lederman et al., 2013), and achieve science learning objectives (Fakhriyah et al., 2017). Science literacy is not only about mastering scientific knowledge but also involves developing skills for critical thinking and making informed decisions (Rahman & Buck, 2023). Students are expected to engage with scientific phenomena, evaluate evidence, and effectively communicate their understanding (Effendi et al., 2021). This underscores the importance of science literacy in addressing complex issues (Rohmah et al., 2022).

According to the OECD (2019), the indicators of science literacy include explaining phenomena scientifically, designing and evaluating scientific inquiries, and interpreting data and evidence scientifically. Science literacy education in schools is a critical component in preparing students to face the challenges of the 21st century. One effective way to enhance science literacy is through interactive and experience-based learning models, such as problem-based and project-based learning (Fauziah et al., 2023; Flores, 2018). Additionally, the implementation of the KWHLAQ strategy in science education can enhance students' curiosity, reading comprehension, and reflective thinking skills, all of which are essential in science education (Sugiarto, 2021). Research also indicates that KWHLAQ can improve students' mastery of science literacy elements, such as content, context, and competencies (Zhang et al., 2023). By integrating various learning methods and involving all stakeholders, it is hoped that students will develop the science literacy skills necessary to face the challenges of the 21st century (Anderson, 2020; Drew & Thomas, 2022).

Problem-Oriented Project Based Learning (POPBL)

POPBL is an educational approach that combines PBL with PjBL, emphasizing active student involvement and real-world problem-solving (Lehmann et al., 2008). Three key elements define POPBL: (1) the problem, (2) the project, and (3) teamwork. POPBL is student-centered, with a greater focus on the learning process (Yasin & Rahman, 2011).

The students typically choose the issues or problems related to the projects. The good problem is characterized as authentic, constructive, integrated, and appropriately complex, fostering independent and lifelong learning and stimulating critical thinking and metacognitive skills (Alwi & Hussin, 2022). The key features of POPBL include learning by doing, real-world problems, the role of the tutor as a guide, teamwork, and the production of final outcomes (Harmer & Stokes, 2014). Students transition from learning by listening to learning by doing, engaging in real-life experiences and activities, which connects them to real-world issues and keeps their interest and motivation high (Bell et al., 2011).

The combination of two learning models, PBL and PjBL, known as POPBL, is expected to be used as a student-centered learning model through project-based learning to address issues in their surroundings (Rizki & Suprapto, 2024). The POPBL model aims to develop students' ability to learn actively, think critically, and solve problems through a learning process focused on practical tasks. It also encourages group discussions (Ibrahim & Halim, 2013). POPBL provides students with the opportunity to apply their knowledge and skills to solve new, real-world problems through projects. This approach is based on the cognitive theories of Jean Piaget, the experiential learning theories of John Dewey and Lewin, and the social cognitive theory of Vygotsky. These theories share the same goal: students learn best when they experience learning firsthand. The most effective experiences are "minds-on and hands-on," which also require social interaction. POPBL offers more meaningful learning because it motivates students. Learning in context makes it easier for students to transfer and relate their knowledge to other relevant contexts.

The POPBL model uses authentic, constructive, integrated, and complex problems to stimulate critical and reflective thinking. According to Rongbutsri (2017), the POPBL model consists of eight stages: group formation, problem formulation, planning, data collection, analysis, problem-solving, reporting, and exam preparation. However, its implementation is often hindered by time constraints (Mihić et al., 2017). To simplify, Ibrohim and his team from Universitas Negeri Malang streamlined the POPBL model into four stages: orientation and problem formulation, organizing learning, designing and implementing the project, and presenting results and evaluation. Previous studies have demonstrated the effectiveness of POPBL in enhancing critical thinking skills, creativity, and collaboration (Filmi et al., 2024; Komalasari et al., 2024; Suwistika et al., 2024).

Pekerti Worksheet

Pekerti is an acronym for Questions, Essential Concepts, Plans of Action, and Initiatives. The Pekerti worksheet is designed to help students formulate problems, identify concepts, carry out projects, and conduct evaluations. Pekerti is adapted from the KWHLAQ framework proposed by Barell (2016), which includes Know, I want to know, How Learned, Action, and Questions. This framework effectively engages students by helping them use their prior knowledge to explore new concepts and apply them in problem-solving scenarios (Kelley et al., 2020). The Pekerti worksheet supports scientific literacy by providing flexibility that can be incorporated into lesson plans and teaching strategies (Fahmawati, 2018). Its primary goal is to promote deeper learning by offering tailored feedback to students (Zhang et al., 2023). Studies have shown that the use of the KWHLAQ strategy not only improves academic performance but also enhances critical thinking skills, surpassing traditional learning methods (Al-Baydani, 2022).

The Pekerti worksheet includes several questions, such as: What questions should I ask? What concepts do I know and want to learn? What plans and actions will I take next? And what initiatives will I take in presenting and evaluating solutions to the problems I have learned? Overall, this strategy is student-centered, with stages designed to help students categorize information before, during, and after lessons. This approach encourages students to be more active in exploring and investigating, which in turn enhances their curiosity, understanding, and reflective thinking abilities (Sugiarto, 2021). The Pekerti worksheet can support students, particularly those in middle school, in applying the POPBL model and fostering deeper thinking skills in project implementation and application. However, the Pekerti worksheet does not emphasize student collaboration and is less effective at honing complex problem-solving skills. Integration with the POPBL learning model, which provides relevant and challenging problems, teaches students to analyze, formulate solutions, and evaluate outcomes (Ezra et al., 2021; Nuraimas et al., 2023), while also encouraging teamwork and group discussions that enhance understanding through social interaction (Ramdhani et al., 2024), is essential. Therefore, integrating the POPBL model with the Pekerti worksheet can lead to a more holistic learning experience, where students can apply knowledge in real-world contexts, collaborate, and develop literacy skills, critical thinking, reflective abilities, and essential problem-solving skills.

RESEARCH METHOD

This study employed a quasi-experimental research design using a pretest-posttest non-equivalent control group. The population consisted of all eighth-grade students at SMPN 2 Alla, Enrekang Regency, South Sulawesi, Indonesia. The selected classes were subjected to an equivalency test. Three groups were randomly selected: the experimental group received instruction through the POPBL model integrated with the Pekerti worksheet, the positive control group was taught using POPBL alone, and the negative control group followed conventional methods. A total of 75 students participated in the study from these three classes. The experimental, positive control and negative control groups were taught using distinct instructional models focusing on the respiratory and excretory systems in Phase D of the Merdeka curriculum. Figure 1 outlines the learning stages for the three instructional methods: POPBL with the Pekerti worksheet, the POPBL model, and conventional learning.

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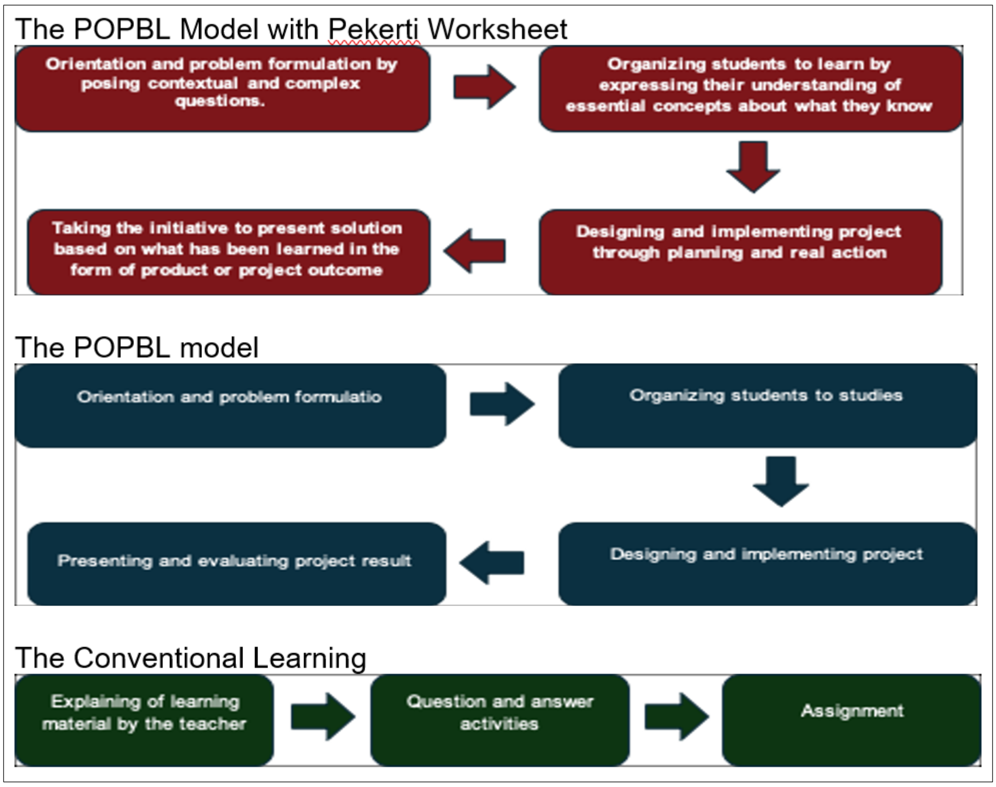
Figure 1. Educational Activities



The research instruments included observation sheets and science literacy tests. The questionnaire, based on the OECD (2019) indicators, covered the following aspects: (1) explaining phenomena scientifically, (2) designing and evaluating scientific investigations, and analyzing data gathered through observation and experimentation both in the laboratory and field settings, and (3) interpreting scientific data and evidence. The test comprised 20 items, including multiple-choice questions, fill-in-the-blank, and essay formats. Prior to data collection, the validity and reliability of the instruments were verified. Validity was assessed using Pearson's product-moment correlation, confirming that all items were valid. Reliability was evaluated through Cronbach's alpha, which indicated high reliability. Data from pretest and posttest assessments on reflective thinking skills were analyzed using inferential statistical methods. A one-way ANCOVA was performed at a 5% significance level to test the hypothesis. Before analysis, the data underwent prerequisite tests, including the One-sample Kolmogorov-Smirnov test for normality and Levene's test for homogeneity of error variances. Following the ANCOVA, a Least Significant Difference (LSD) test was conducted to assess the significance of differences in average scores between treatment groups.

RESULTS

The students' scientific literacy research data has passed the prerequisite tests, allowing for the continuation of hypothesis testing. These prerequisite tests include normality and homogeneity tests. The results of the normality and homogeneity tests are presented in Table 1.

Table 1. Normality and Homogeneity Test Result of Scientific Literacy

No.	Variable	Test		N	p	α
1.	Scientific Literacy	Normality	Pretest	75	0.200	0.05
		Normality	Posttest	75	0.200	0.05
		Homogeneity	Posttest	75	0.839	0.05

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Based on Table 1, the significance values (p-values) of the normality and homogeneity tests are greater than 0.05, indicating that the data is normally distributed and homogeneous. Subsequently, hypothesis testing was conducted using a one-way ANCOVA test with SPSS version 26. Pretest and posttest results assessing the effectiveness of the POPBL with the Pekerti Worksheet, POPBL, and conventional learning models on scientific literacy are presented in Table 2.

Table 2. Mean Pretest Posttest Scientific Literacy Scores

No	Variable	Pretest	Posttest	Difference	Improvements (%)
1	POPBL+Pekerti Worksheet	42.98	83.08	40.05	93.18
2	POPBL	42.60	71.76	29.16	68.45
3	Conventional	44.50	57.50	13.00	29.21

The results of the ANCOVA test on the scientific literacy variable indicate that the learning model has a significance value of 0.000, which is smaller than the alpha level of 0.05 ($p < \alpha$). The research hypothesis is accepted, suggesting that the POPBL with Pekerti worksheet learning model influences students' scientific literacy. A summary of the ANCOVA results for the scientific literacy understanding variable is presented in Table 3.

Table 3. The Result of ANCOVA Variables Understanding Scientific Literacy

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	8942.517[a]	3	2980.839	136.197	0.000	0.852
Intercept	3954.078	1	3954.078	180.664	0.000	0.718
Scientific literacy	580.603	1	580.603	26.528	0.000	0.272
Learning model	8737.184	2	4368.592	199.604	0.000	0.849
Error	1553.928	71	21.886			
Total	387826.31	75				
Corrected Total	10496.445	74				

The ANCOVA results for the learning model indicate significant findings, specifically that the model influences students' scientific literacy. The analysis was furthered with the LSD test at a significance level of 0.05 to determine the adjusted mean differences among each learning model. The results of this test are presented in Table 4. The LSD test results reveal differences in the adjusted average scores of students' scientific literacy across the learning models. The adjusted mean for the POPBL with Pekerti Worksheet differs from both POPBL and Conventional models. The notation differences among the three learning models suggest that the adjusted average scores for the POPBL with the Pekerti Worksheet are significantly different from those for the POPBL and Conventional models.

Table 4. LSD Model Test Results on Scientific Literacy

Model	Corrected Average	LSD notation
Konvensional	56.991	a
POPBL	72.103	b
POPBL + Pekerti Worksheet	83.250	c

DISCUSSION

The effectiveness of the POPBL model combined with Pekerti worksheets was tested to measure how well the model can empower the scientific literacy of eighth-grade students in biology education. The effectiveness of the learning model was assessed by comparing the average scores obtained by students in the class taught using the POPBL model combined with Pekerti worksheets (experimental group) with those obtained by students in the class taught using the POPBL model (positive control) and the conventional model (negative control). An effective learning model is indicated by the learning mastery achieved by students when participating in lessons using the proposed model (Plomp, 2013). Based on the results of the One-Way ANCOVA analysis, there was a significant difference in the science literacy of students taught with the POPBL model combined with Pekerti worksheets compared to those taught with the POPBL model and conventional learning.

The POPBL model combines PBL and PjBL, creating a learning environment that fosters the critical, creative, and collaborative skills needed in the 21st century (Chen, 2015; Rizki & Suprapto, 2024). By involving students in real-world problems, POPBL helps them apply scientific concepts, deepening their understanding of science (Eliyawati et al., 2020). Students analyze problems, design experiments, and interpret data, which develops their understanding of scientific inquiry (Murugan & Yasin, 2024). This approach aligns with constructivist theory, where students build knowledge through experience and reflection (Saghafi, 2021). POPBL also motivates students and prepares them for future scientific challenges by equipping them with the skills to tackle complex problems (Lim et al., 2023). One way to optimize problem-solving in the POPBL model in junior high school is by designing different learning activities in the worksheet, compared to the POPBL model or conventional learning.

The student worksheets based on the POPBL learning model, integrated with the Pekerti worksheet, are designed to guide students in PjBL that focuses on everyday contextual problems. The Pekerti worksheet is adapted from the KWLHAQ framework, which provides a structured approach to guide students through their learning experiences. Using this framework allows students to create a personalized learning path that addresses their interests and knowledge gaps, thereby increasing their motivation and engagement (Zhang et al., 2023). Furthermore, the Pekerti worksheet supports students' understanding and application of scientific concepts (Fahmawati, 2018), while encouraging them to connect prior knowledge with new information in problem-solving (Kelley et al., 2020). The Pekerti worksheet in the POPBL model provides a more structured framework for the learning process, helping students plan, implement, and evaluate their learning. The POPBL model, which focuses on applying knowledge to solve problems within the context of a project, differs from conventional learning, which places more emphasis on memorization of material without delving into understanding or application. Learning that focuses solely on conceptual understanding can diminish the quality of education, as it fails to develop the complex thinking skills necessary in the modern world (Purnomo et al., 2020).

The POPBL model, combined with Pekerti worksheets, begins with the orientation and problem formulation stages, where students are prompted to understand the context of the problems they will face and identify gaps in their knowledge. The integration of Pekerti worksheets, particularly the questions posed during this stage, helps students explore critical questions related to the issues at hand. This phase encourages students to ask questions and think more deeply about relevant scientific concepts, which can enhance their science literacy. By questioning problems in depth, students are not only actively engaged in the learning process but also develop critical thinking skills essential for understanding scientific concepts holistically (Kelley et al., 2020).

Students' ability to ask questions after reading and watching videos related to the raised issues can help develop their science literacy, particularly in the indicator of explaining phenomena scientifically. Activities that involve identifying problems and formulating questions have been shown to improve students' science literacy skills (Rahmatika et al., 2022). Science literacy, which involves using knowledge to interpret scientific phenomena and solve problems, requires effective questioning skills (Pujawan et al., 2022). Through questioning activities, students can evaluate, reflect, and analyze scientific information, thereby enhancing their literacy (Pamungkas et al., 2018). Questioning skills in PBL or PjBL models also encourage deep engagement with scientific concepts (Cantona et al., 2023), as questions stimulate investigation and a deeper connection with the material (Li & Arshad, 2017). This activity aligns with Piaget (1964) theory of active learning, which posits that learning is an active process in which students construct new knowledge from their experiences. The orientation and problem formulation activities, through reading and watching videos, train students to construct knowledge and develop analysis and creativity in identifying problems (Harimurti, 2023; Priyatni & Martutik, 2020). This is in line with Ausubel's (1960) meaningful learning theory, which demonstrates that such activities strengthen students' understanding by linking theoretical concepts to concrete examples. Problem identification also trains students to think more critically (Morse et al., 2019) and aligns with Vygotsky (1978) constructivist theory, which views learning as the construction of knowledge through social interaction and the environment.

The second stage is organizing students to discover and understand essential concepts. Students are guided to explore these essential concepts to better understand the issues through group discussions and exploration of various sources related to the human respiratory and excretory systems. Afterward, they are guided through Pekerti worksheets to write down what they know (know) and what they want to learn more about (want) so they can summarize their understanding of the essential concepts within the material being taught. This stage of exploring essential concepts can help develop students' science literacy, particularly in explaining scientific phenomena. Exploration plays a vital role in improving science literacy, encompassing not only an understanding of scientific concepts but also the ability to engage in scientific inquiry and critically evaluate information (Vandegrift et al., 2020). Studies show that involving students in informal reasoning about issues related to scientific phenomena can significantly enhance their science literacy (Ozden, 2020). This pedagogical strategy allows students to apply scientific concepts to real-world problems, thus deepening their understanding and appreciation of science (Faria et al., 2015). Furthermore, using scientific phenomena that are contextual and close to students' lives has been proven to increase engagement and comprehension, thereby improving their science literacy (Verawati & Wahyudi, 2024). Additionally, the use of texts and multimodal resources can support the development of science literacy by providing various contexts for exploration and learning (Buchholz & Pyles, 2018; Wright et al., 2024). At this stage, the teacher also checks for possible misconceptions that may arise from the material being studied and corrects them. The cognitive activities facilitate students' deeper transformation of knowledge (Kohler, 1947; Leatherman & Cleveland, 2020). This is supported by Vygotsky (1980), who viewed the question-and-answer process as closely linked to social interaction, which encourages students to collaborate in reaching a shared understanding and deeply interpreting problems.

The third stage involves designing and implementing the project with a structured plan and actions. In this stage, students are guided through Pekerti worksheets to brainstorm ideas and develop alternative solutions in groups (how). Then, they plan and implement the project (action) to realize the alternative solutions that have been collaboratively determined with their group members. At this stage, students' science literacy is enhanced in the aspect of designing and evaluating scientific inquiry. This learning approach encourages active involvement through hands-on problem-solving activities, requiring students to gather information, explore concepts, interpret data, and synthesize findings related to real-world issues. The ideas developed by students, based on comprehensive information gathering, require a deeper understanding of scientific concepts and methodologies (Hwang & Chen, 2019). Furthermore, structured project activities can significantly improve students' understanding of scientific concepts (Kurniasari & Salshabilla, 2023). Ongoing project planning serves as an essential risk management tool that can be applied in educational contexts to enhance the learning experience (Yu et al., 2018). Štrok et al. (2023) emphasize that careful organization of project activities is crucial to achieving educational goals within the planned timeframe.

The implementation of project activities plays a vital role in enhancing science literacy among students. Project activities significantly contribute to the development of students' project competencies, transforming the learning process into a more dynamic and engaging experience (Kirillova et al., 2021). This active involvement is critical for developing a deeper understanding of scientific concepts and methodologies, as it encourages students to interact directly with the material (Anderson, 2020). These learning activities are grounded in Piaget's (1964) constructivist theory, where students actively engage in the learning process by planning, implementing, and reflecting on their projects, which allows them to build a deeper understanding of scientific concepts. Through group projects, students learn to communicate, share ideas, and solve problems together, which is essential for developing both social and scientific skills in line with Johnson and Johnson's (1991) collaborative learning theory. Planning and implementing projects help students link new concepts with prior knowledge, thereby enhancing understanding and information retention, as outlined in cognitive theory (Ausubel, 1968).

The fourth stage is to present solution initiatives in the form of project outcomes and to evaluate the learning process and results. Each group is guided to present their solution initiatives based on the learning experiences gained during the learning process and project implementation. This learning activity empowers students' literacy in the aspect of interpreting data and evidence scientifically. Research shows that involving students in formulating solution initiatives and making informed decisions can improve their science literacy (Permanasari et al., 2021). PBL or PjBL, which continuously confronts students with relevant issues, also enhances their analytical skills in providing effective solutions (Mukti et al., 2023). The development of innovative educational resources, such as multimedia and interactive worksheets, increases student engagement and deepens their understanding of scientific concepts (Sahnaz & Kuswandi, 2023; Yuningsih et al., 2022). Kurniasari et al. (2023) emphasize the importance of authentic learning experiences in developing a deep understanding, while (Jie et al., 2024; Rasyid & Khoirunnisa, 2021) add that evaluations should consider both the process and team collaboration. Zou et al. (2023) argue that traditional evaluation methods are inadequate for assessing PBL, which requires a new evaluation framework. Wang (2023) highlights the importance of evaluation criteria that address the unique challenges of PjBL. Structured approaches, such as worksheets, can assist in evaluating both the process and outcomes (Muslim et al., 2020). The activity of presenting solutions and evaluating the process and outcomes of projects emphasizes hands-on learning experiences, in line with Kolb's (1984) experiential learning theory and Bandura’s social learning theory, both of which support the enhancement of students' evaluative skills.

CONCLUSION

Based on the findings and discussion of this study, it can be concluded that the POPBL model, combined with the Pekerti Worksheet, has a significant effect on students' science literacy. This conclusion is supported by the ANCOVA hypothesis test results, which showed an F value of 199.604 and a p-value of 0.000, where $p < \alpha$ ($\alpha = 0.05$). Additionally, the LSD test indicated a significant difference between the conventional learning model, POPBL, and POPBL with the Pekerti Worksheet. This was evident from post-test average scores, with the POPBL model using the Pekerti Worksheet achieving the highest score (83.250), followed by the POPBL model (72.103) and the conventional learning model (56.991). Future research should focus on developing other innovative learning models that incorporate various media.

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DECLARATION OF CONFLICTING INTERESTS

The authors declare that there are no conflicts of interest related to the publication of this paper.

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