Biosfer: Jurnal Pendidikan Biologi, 18(2), 276-289 (2025)

Biosfer: Jurnal Pendidikan Biologi

Journal homepage: http://journal.unj.ac.id/unj/index.php/biosfer

Improving students' scientific literacy through a problem-based learning model integrated with socio-scientific issues on ecosystem learning

Agustina Nur Khairrunisa*, Iwan Ridwan Yusup, Epa Paujiah

Biology Education, Faculty of Teacher Training and Education, UIN Sunan Gunung Djati, Indonesia

*Corresponding author: iwanyusuf@uinsgd.ac.id

ARTICLE INFO

Article history

Received: 31 May 2025

Revised: 13 June 2025

Accepted: 20 June 2025

Keywords:

Problem Based Learning (PBL)

Scientific literacy

Socio-Scientific Issues (SSI)

ABSTRACT

Scientific literacy is recognized by the World Economic Forum as one of the 16 essential skills for the 21st century. However, the scientific literacy of Indonesian students remains relatively low based on PISA results. This study aims to examine the enhancement of students' scientific literacy through implementation of Problem Based Learning (PBL) model based on socio-scientific issues (SSI) on ecosystem learning. This research used a quasi-experimental study with a non-equivalent control group design. The population consisted off all 7th grade in the academic year 2024/2025, totaling 108 students. Two classes were selected as samples: 28 students in the experimental class and 26 students in the control class. Data collection instruments include tests, observation, and questionnaire. The data were analyzed using N-Gain to measure improvement and inferential statistics to test significance. These findings suggest that Problem Based Learning (PBL) based on socio-scientific issues (SSI) effectively enhances students' scientific literacy. This research can be an alternative strategy, and reference for teachers and schools in implementing innovative learning that supports scientific literacy development.

INTRODUCTION

Scientific literacy is one of the 16 skills in 21st-century considered important by World Economic Forum, because it includes the ability to research, evaluate, and use scientific information in decision-making, especially amidst the rampant disinformation in digital era (Sariningrum et al., 2018). Programme for International Student Assessment (PISA) 2025 emphasizes the importance of scientific literacy as a crucial competency in responding to science-based issues critically and creatively (Osborne et al., 2023). Unfortunately, the results of PISA measurement show that the scientific literacy of Indonesian students is still relatively low (Rohmawati et al., 2018). In 2015, the assessment of PISA showed that Indonesian students had an average score of 403, below the global average of 493, positioning the country at 62nd out of 69 participating nations. In 2018, Indonesia scored an average of 396, significantly below the global average of 489, placing the country at 74th out of 78 participating nations (Khikmah et al., 2024). The downward trend continued in 2022, with an average score of 383, still below the global average of 485. That year, Indonesia ranked 71st out of 81 countries (Putri et al., 2025). Previous study by Putri et al., (2018) revealed that students' scientific literacy in one of Junior High School was low in 3 indicators. A similar finding was reported by Permatasari (2022), who noted that the scientific literacy ability of students at a Junior High School is obtained in a low category in 3 aspects, namely, explaining scientific phenomena, evaluating and designing scientific investigations, and interpreting data and evidence scientifically. Based on the research pre-interview with science teacher at MF Junior High School (pseudonym), stated that students still experience difficulties in solving analytical problems such as interpreting data, explaining scientific phenomena, and drawing conclusions based on scientific evidence. This is in line with the findings of Ramli et al., (2021) who stated that students' scientific literacy is in low category for explaining scientific phenomena indicator and very low for interpret scientific data and evidence indicator. According to Isti et al., (2020), only 20% of students were able to observe, analyze, and draw conclusions based on data. Putri et al., (2025) found that students' achievement in construct and evaluate designs for scientific inquiry was 53%, and 69% in use scientific information.

The low scientific literacy of students is caused by various factors, including the selection of inappropriate textbooks, misconceptions, low reading skills, and an unsupportive learning environment (Fuadi et al., 2023). In addition, learning that is not contextual and not relevant to everyday life is also the main cause (Fibonacci & Sudarmin, 2014; Rohmaya, 2020), including the learning process that is still conventional and relies on conceptual mastery (Toharudin et al., 2011; Permanasari et al., 2021). The results of interviews with science teachers at MF Junior High School (pseudonym) showed that learning is still conventional, dominated by lecture methods, videos, and discussions without an in-depth approach to scientific process. Students tend to memorize concepts rather than understand and relate them to everyday life, so they only get standard concepts (Fauziah et al., 2019; Azizah, 2021). This is in line with the findings of Yenni et al., (2017) who stated that learning which only focuses on content, not process and context, contributes to low scientific literacy. Based on the explanation above, the lack of contextual science learning is one of the main factors contributing to students' low scientific literacy. Therefore, science learning in schools needs to be improved by not only focusing on the transfer of knowledge, but also by encouraging students to apply concepts in solving real-world problems, one of which can be achieved through the implementation of problem-based learning based on socio-scientific issues.

Problem Based Learning (PBL) model is an effective learning approach to improve students' scientific literacy, because it places problems as starting point of learning and encourages students to engage in the learning process independently and collaboratively (Graaff, 2003; Hestiana et al., 2020). PBL model encourages students to formulate problems, analyze data, conduct investigations, and make decisions based on scientific evidence (Savery et al., 2001), so they are able to link science concepts to real life and improve scientific thinking skills (Graaff, 2003). PBL model can be combined with Socio-Scientific Issues (SSI) approach which raises social issues related to science and has an impact on society (Yenni et al., 2017). The combination of SSI-based PBL has been shown to provide real problems that encourage students to think critically, collect and analyze scientific evidence, and understand the scientific process more deeply (Graaff, 2003). The results of Yolida's (2021) study showed that the application of the SSI-based PBL Model can significantly improve students' scientific literacy. Thus, SSI-based PBL learning has potential to support the improvement of students' scientific literacy.

Biology learning, especially on the topic of Ecosystems, is not sufficient by merely memorizing factual knowledge (Permatasari, 2022). In ecosystem learning, contextual aspect is very important because the scope of ecosystem problems is closely related to everyday life, which requires not only knowledge, but also attitudes and skills to reflect and solve existing environmental problems (Subiantoro et al., 2013). Permanasari et al. (2021) stated that ecosystem material is a theme that has many issues present in society, such as deforestation, environmental pollution, animal exploitation, and even global warming and climate change. The ecosystem material requires scientific literacy competencies in its learning process (Putri et al., 2025); therefore, it was selected as the focus of this study.

Research on the Problem-Based Learning (PBL) Model to improve scientific literacy has been conducted by several researchers. One of them by Hestiana et al., (2020) showed an increase in pretest and posttest results, thus proving that there was an increase in students' scientific literacy abilities, especially in the competency aspect. Yani et al., (2022) conducted a similar study but using different learning materials, and their findings demonstrated that the Problem-Based Learning Model can enhance students' scientific literacy. The latest research by Putriyani (2024) showed that there was an increase in the competency aspect of students' scientific literacy after the implementation of the PBL Model. Similar studies have also been conducted in various countries, demonstrating the global relevance and effectiveness of the PBL model in science education. A study conducted in Spain by Muñoz et al., (2023) showed that PBL was effective in enhancing students' scientific skills, such as asking in-depth and systematic questions, as well as increasing student engagement in the science learning process. Furthermore, research in Turkey by Uluçinar (2023) revealed that the PBL method used in science education had a significant impact on students' scientific competencies, related to identifying and analyzing scientific problems, interpreting data, proposing evidence-based solutions, and drawing logical conclusions and decision-making. Another study by Ke et al., (2021) in United States found that the application of socio-scientific issues (SSI) could improve students' scientific literacy skills. The use of SSI-based learning models has been shown to help students connect scientific knowledge with social, political, and economic contexts through real-world issues. This approach not only deepens students' understanding of scientific concepts but also strengthens their critical thinking, decision-making, and reasoning skills. However, research that integrates the PBL Model with SSI, particularly in ecosystem-related material, has not yet been implemented at MF Junior High School (pseudonym). Therefore, this study aims to examine the improvement of the students' scientific literacy after the use of Problem Based Learning (PBL) Model Based on Socio-Scientific Issues (SSI) on Ecosystem learning.

METHODS

Research Design

The approach used in this study is a quantitative approach with the research method used were quasi-experimental method. This study aims to analyze whether there is an increase in students' scientific literacy, especially in the competency aspect after being given treatment in the form of implementing the Problem Based Learning (PBL) model based on Socio-Scientific Issues (SSI) on ecosystem learning. This research uses a Nonequivalent control group design. According to Jaedun (2011) this design can be illustrated in Table 1.

Table 1
Nonequivalent control group design

No	Group	*Pretest*	Treatment	*Posttest*
1	Experiment	O_1	X	O_2
2	Control	O_3	-	O_4

The description for the table is as follows: (1) O_1: Initial average value of the Scientific literacy of students in the experimental class; (2) O_2: Final average value of the Scientific literacy of students in the experimental class; (3) O_3: Initial average value of the Scientific literacy of students in the control class; (4) O_4: Final average value of the Scientific literacy of students in the control class; (5) X: Problem Based Learning (PBL) model based on Socio-scientific Issues (SSI); (6) -: Direct instruction model learning.

Population and Samples

This research was conducted at MF Junior High School (pseudonym). The population consisted off all 7th grade in the academic year 2024/2025, totaling 108 students, A total of 54 students from two classes were selected as the research sample. The sample was selected using a purposive sampling technique, which involves the deliberate selection of subjects based on specific criteria relevant to the objectives of the study (Jaedun, 2011). Based on academic equivalence, two classes were chosen (Table 2). While the sample may not statistically represent the entire population, it is sufficient to meet the experimental design requirements. This is supported by Arikunto (2012) who suggests that if the number of subjects is less exceeds 100, we may take around 25%–30% of the total population as a representative sample.

Table 2
Research Samples Classification

No	Class	Numbers of Students	Group Type
1	VII-B	26	Controll Class
2	VII-C	28	Experimental Class

Instrument

Data collection instruments include tests, observation, and questionnaire. Data were collected through several techniques: (1) observation to gather information on the learning implementation process; (2) written tests to assess the development of students' scientific literacy before and after the learning activities; and (3) questionnaires to capture students' reflections following the learning process. The observation instrument for learning implementation includes the phases of Problem Based Learning Model referring to Arends (2008) as cited in Azizah (2021). The scientific literacy test and questionnaire instrument was constructed with reference to the PISA 2025 scientific literacy framework, which outlines three core competencies: (1) explaining phenomena scientifically; (2) constructing and evaluating scientific inquiry designs and interpreting scientific data and evidence critically; and (3) researching, evaluating, and utilizing scientific information for decision-making and action. Each item in the instrument were subjected to content validation by two experts in biology education to ensure alignment with the intended indicators and cognitive demands.

The scientific literacy test was subjected to a try-out process to determine the validity, reliability, item difficulty level, and discrimination index of each test item. Based on item analysis, 20 multiple choice items demonstrating acceptable levels of validity, difficulty, discrimination, and internal consistency were retained. The reliability of the refined instrument was determined using Cronbach's Alpha, resulting in a coefficient of 0.82, indicating a high level of internal consistency referring to Jaedun (2011). The test blueprint for each scientific literacy indicators are illustrated in Table 3.

Table 3
Test Blueprint for Scientific Literacy Items

No	Scientific Literacy Indicators	Total Items	Item Numbers
1	Explain phenomena scientifically	6	1, 2, 5, 9, 13, 16
2	Construct and evaluate designs for scientific enquiry and interpret scientific data and evidence critically	8	3, 6, 8, 10, 15, 17,18, 20
3	Research, evaluate and use scientific information for decision making and action	6	4, 7, 11, 12, 14, 19

Procedure

The research procedure was carried out in two main stages: the preparation stage and the implementation and data collection stage. During the preparation stage, research proposals and instruments were developed, validated, and research permits were obtained. In the implementation and data collection stage, the learning model was applied to experimental class. The control class received conventional instruction, while the experimental class was taught using a problem-based learning (PBL) model based on Socio-Scientific Issues (SSI) referring to Arends (2008) as cited in Azizah (2021). The stages of Problem Based Learning (PBL) Based on Socio-Scientific Issues (SSI) implemented in the experimental class are illustrated in the Table 4.

Table 4
Stages of Problem-Based Learning (PBL) Based on Socio-Scientific Issues (SSI)

No	PBL Syntax	SSI Stages	Learning Activity
1	Student orientation to the problem	Problem analysis	teacher presents the context of socio-scientific issues related to the ecosystem which will hone students' ability to identify scientific issues
2	Organizing students to learn	-	students are guided to create questions (problem formulation) and temporary answers (hypotheses), and divide tasks with their groups, which will hone students' ability to make predictions from a scientific phenomenon
3	Assisting students and groups in their investigations	Clarification of the science & Refocus on the socio-scientific dilemma	students are encouraged to lead the investigation process, connecting theory and practice, and applying the knowledge and skills they have to formulate appropriate solutions to the problems they face (Savery et al., 2001) so they will hone students' abilities in designing investigation designs, interpreting scientific data and evidence, and researching, evaluating, and using scientific information for decision making and action
4	Developing and presenting work results	Role-playing task	students are guided to plan and prepare appropriate work results such as reports and present their work results to other groups to hone students' abilities in explaining scientific phenomena
5	Analyzing and evaluating the problem-solving process	Meta-reflective activity	students will reflect on the investigation process and draw conclusions, which will hone students' abilities in evaluating, using scientific information for decision making and action.

Data Analysis Techniques

The data analysis method used in this research is to calculate the percentage of observation results (observed by observers) regarding the implementation of the stages in learning carried out by teachers and students during the learning process. Analysis of the Scientific literacy test results includes N-Gain test and inferential statistical test. The N-Gain test is used to determine the difference between initial score and final score so that the category of improvement can be determined. Meanwhile, inferential statistical test is used to assess the significance of the improvement (Khikmah et al., 2024). Analysis of the student reflection questionnaire was carried out quantitative descriptively to determine student reflection after learning.

RESULTS AND DISCUSSION

1. Learning Implementation

Learning implementation was observed by one observer during two meetings. The results of learning implementation are presented in Table 5, which show the level of implementation of teacher performance and student activity in two meetings based on three main stages, namely introduction, core activities (SSI-based PBL syntax), and closing.

Table 5
Results of Observations of Teacher and Student Activities in Experimental Class

No	Stage	Object	Meeting	Mark (%)	Category	Mean	Category
1	Preliminary	Teacher	1st	100	Very Good	100	Very Good
			2nd	100	Very Good		
		Students	1st	100	Very Good	100	Very Good
			2nd	100	Very Good		
2	Core Aktivity	Teacher	1st	94	Very Good	97	Very Good
			2nd	100	Very Good		
		Students	1st	87	Very Good	92	Very Good
			2nd	96	Very Good		
3	Closing Activities	Teacher	1st	100	Very Good	100	Very Good
			2nd	100	Very Good		
		Students	1st	100	Very Good	100	Very Good
			2nd	100	Very Good		

The results show that SSI in PBL was well implemented on the first and second days/meeting. The SSI in PBL begins with preliminary activities. Based on Table 5, implementation of the preliminary stage obtained a very high score of 100, both in the first and second meetings, which shows that teacher has implemented it very well. The preliminary stage is the initial foundation in the learning process that functions so that students are ready to learn and have high motivation. Some of the main activities in this stage include providing motivation, apperception, and conveying learning objectives (Nasirun et al., 2019). Pedagogically, providing motivation at the beginning of learning plays an important role in arousing students' interest and enthusiasm to be actively involved in the learning process (Fathurrohman et al., 2012). Meanwhile, apperception acts as a bridge between students' prior knowledge and new material to be learned (Asmara et al, 2023). Learning will be more meaningful if new information can be integrated with the cognitive structure that students previously had (Puteri, 2018). According to Schmidt (1995), activating this prior knowledge is very important because it prepares students to receive and understand new information. In other words, linking old knowledge to new problems makes the learning process more meaningful and effective. Moreover, the results of monitoring teacher and student activities in Table 5 show that the closing stage gets a maximum score of 100 (very good) both in the first meeting and in the second meeting. This closing stage includes one of the reflection activities. Reflection functions as a forum for students to re-evaluate what they have learned, as well as internalize the concepts and skills acquired during the learning process (Fathurrohman et al., 2012).

The syntax of the PBL model according to Arends (2008) in Azizah (2021) are presented in Table 4. The scores obtained for each stage are illustrated in Figure 1, indicating that the implementation of the learning process was carried out very well.

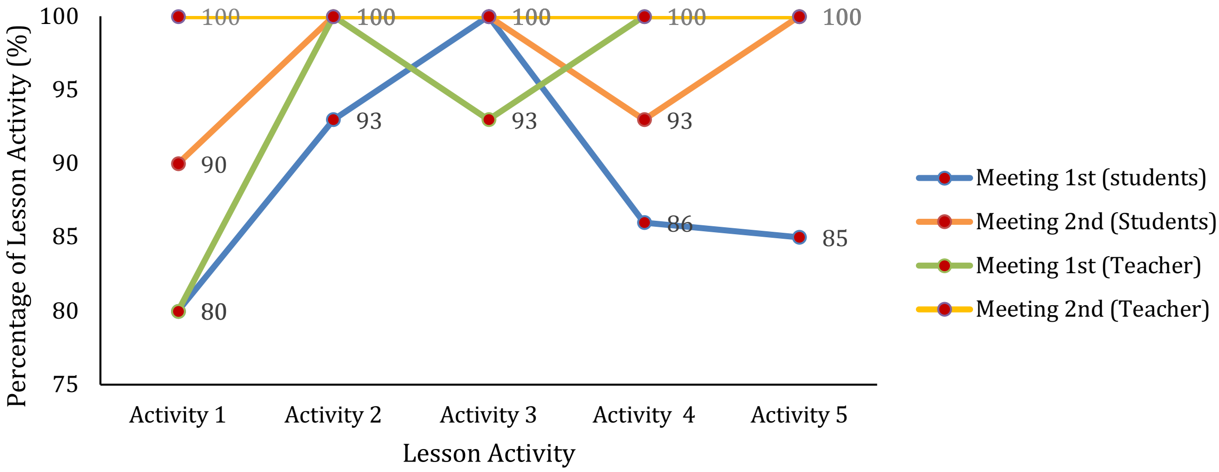

Figure 1. Lesson Activity Data with PBL Models. Note: activity - (1) Student orientation to the problem; (2) Organizing students to learn; (3) Assisting students and groups in their investigations; (4) Developing and presenting work results; (5) Analyzing and evaluating the problem-solving process.

The PBL-SSI process proceeds through several structured stages, beginning with the introduction of complex and authentic SSI problems. Students, either individually or in groups, work to understand the problem, conduct research, and identify the necessary information. Then, students formulate hypotheses and seek solutions through discussion and collaboration (Barrows, 1986). Subsequently, students apply problem-solving strategies they have learned, reflect on the process and outcomes, and evaluate the solutions they have developed (Asmara et al., 2023). The teacher acts as a facilitator who supports the development of students' cognitive and collaborative skills throughout this process (Azizah, 2021). Through such a learning process, students are encouraged to deeply understand the problem, seek solutions both independently and collaboratively, and apply scientific steps in solving the problem (Putriyani, 2023). This process helps students develop stronger problem-solving skills as they learn to identify issues, formulate hypotheses, test solutions, and reflect on the results (Muñoz et al., 2023). Based on Figure 1, the student orientation stage towards the problem obtained the lowest score (Figure 1). This problem orientation is very important because it acts as the basis for the learning process, so that it determines the direction of learning (Asmara et al., 2023). The low score at this stage can be caused by several factors, including the lack of student experience in dealing with complex open-ended problems, such as socio-scientific issues (SSI) that are not familiar to most students so students tend to be passive participation (Subiantoro et al., 2013). In addition, the orientation stage is often shortened due to time pressure, so teacher do not have time to provide a strong introduction.

When viewed from the learning stages (introduction, core, closing), the value at the core activity stage is the lowest achievement compared to the values of the preliminary and closing stages (Table 5). Nasirun et al., (2019) stated that the core activity is the most crucial stage because at this stage the learning model, learning method, learning media and learning resources are applied. Several factors that cause this stage not to be implemented properly include: (1) The habit of students learning style, which tends to rely more on listening the teacher's explanation rather than reading and studying the material independently causes students to not easily or slowly respond to the learning scenarios applied. Most students only read part of the contents of the teaching material to find answers, rather than to understand the content comprehensively; (2) students have difficulty understanding and working on worksheets, especially because the substance of the material is quite complex and requires high analytical skills. Although the material is interesting, most students do not yet have sufficient critical thinking skills to solve problems in the worksheet in depth. Components in the preliminary activities and closing activities are were already familiar to both teachers and students so that they can be carried out very well, while the core learning activities become difficult due to complex class dynamics, differences in student characteristics, and the need to improve teacher skills in carrying out in-depth interactions and supporting students' thinking processes (Nasirun et al., 2019).

2. Students' Scientific Literacy

Students' Scientific literacy is reflected in the N-Gain results analyzed from the pretest and posttest results of the experimental and control classes in Table 6. The overall N-Gain results indicate a moderate improvement in scientific literacy competence in the experimental class, both in the average score and across the three indicators. In contrast, the control class showed only a low improvement, as reflected in both the overall average and each of the indicators. These results indicate that providing treatment PBL learning model in the experimental class was able to improve students' scientific literacy better than using conventional methods. This finding is in line with the research of Hanifha et al. (2023) that there was an increase in the scientific literacy score with an N-Gain score of 0.57, which is included in the moderate category. In addition, Nainggolan et al. (2021) described an increase in students' scientific literacy in the experimental class.

Table 6
N-Gain Calculation in Experimental Class and Control Class

No	Scientific literacy Indicators	Experimental Class			Controlling Class		
		Pretest	Posttest	N-Gain	Pretest	Posttest	N-Gain
1	Explain phenomena scientifically	52.38	80.35	0.58	62.17	68.58	0.16
2	Construct and evaluate designs for scientific enquiry and interpret scientific data and evidence critically	52.23	80.80	0.59	49.03	54.32	0.10
3	Research, evaluate and use scientific information for decision making and action	55.95	76.19	0.45	51.92	60.89	0.18
	Mean	53.52	79.11		54.37	61.27	
	Overall N-Gain		0.53			0,10	
	Category		medium			Low	

The Explain phenomena scientifically indicator measures students' ability to understand scientific concepts and use them to explain phenomena that occur in everyday life, not just remembering these scientific concepts (Berland et al., 2008). The results of the analysis showed that the experimental class experienced a moderate improvement, while the control class demonstrated only a low level of improvement (Table 6). This shows that the learning approach applied in the experimental class is more effective in encouraging students to understand scientific concepts and relate them to real phenomena. In accordance with Khikmah et al., (2024) that there was an increase in the Explain phenomena scientifically indicator with an N-Gain score of 0.72. Another findings by Arding et al., (2020) showed that the explains the phenomenon scientifically obtained a value of 32.19 and also in the research of Hestiana et al., (2020) that this indicator obtained a value of 42.8 and is included in the medium category. Uluçinar (2023) revealed that PBL method can improve students' scientific competencies, especially in identifying and analyzing scientific problems. Thus, proving that including social science issues in PBL learning can increase the ability to Explains phenomena scientifically. This is due to the fact that during the stage of student orientation to the problem, organizing students to learn, and developing and presenting work results in PBL syntax, students are given the opportunity to organize their findings and communicate their solutions through presentations, reports, or other forms of output (Schmidt, 1995). This process encourages students to construct explanations for scientific phenomena based on the evidence they have gathered during the investigation phase. In presenting their work, students are required to articulate scientific reasoning, explain cause-and-effect relationships, and connect scientific concepts to real-world contexts (Uluçinar, 2023). As a result, this stage directly fosters the ability to explain scientific phenomena.

In the Construct and evaluate designs for scientific inquiry and interpret scientific data and evidence critically indicator, the experimental class showed the highest level of improvement with a moderate category, whereas the control class demonstrated only a low level of improvement (Table 6). Consistent with the findings of Hidayat et al. (2024) showed that there was an improvement in Construct and evaluation designs for scientific inquiry and interpret scientific data and evidence critically indicator at the moderate category level. Rahayu et al. (2022) reported similar findings, that this indicator obtained a value of 0.70. According to Husniyyah et al. (2023), the indicator demonstrated a positive development, with an average gain of 37.90. The application of the PBL model in learning can improve the aspects of data interpretation and evidence scientifically (Putri et al., 2025). Uluçinar (2023) revealed that the PBL method used in science education had a significant impact on students' scientific competencies, especially in interpreting data. Another study by Muñoz et al. (2023) showed that PBL was effective in enhancing students' scientific skills, such as asking in-depth and systematic questions, as well as increasing student engagement in the science learning process. Thus, proving that including PBL-SSI learning can increase the ability to construct and evaluate designs for scientific inquiry and interpret scientific data and evidence critically. This is because during the stage of assisting students' investigations in PBL, syntax encourages active student participation in designing investigations, analyzing and connecting information/data, interpreting and understanding data and scientific evidence from the data represented (Graaff, 2003). Throughout the investigation process, students engage with various sources of information, such as texts, tables, and graphs (Putri et al., 2025). Under the teacher's guidance, they are encouraged to develop skills in identifying variables, recognizing patterns, comparing data, and drawing conclusions from graphical data (Asmara et al., 2023). Furthermore, working in groups facilitates peer discussion, which deepens students' understanding of data visualizations. Through collaborative analysis, students are exposed to multiple perspectives, allowing for a more comprehensive interpretation of graphical information (Uluçinar, 2023). This learning supports students to build experiences through the application of science in everyday life (Hestiana et al., 2020). This gives students the opportunity to gain deeper learning and concrete learning experiences so that these skills can develop significantly (Graaff, 2003).

The Research, evaluation and use of scientific information for decision-making and action indicator showed the lowest N-gain improvement compared to the other indicators. Even so, the experimental class demonstrated a moderate improvement, while the control class showed a low level of improvement (Table 6). This indicator requires students to find scientific explanations as evidence for a statement or conclusion, choose alternative statements that are still related to the evidence, provide reasons to oppose certain conclusions, and identify assumptions made in concluding (Thomson et al., 2013). The results of the study conducted by Putri et al. (2025) revealed that students' scientific literacy in this competency falls within the proficiency category. Uluçinar (2023) reported that problem-based learning had a significant impact on students' scientific competencies, related to proposing evidence-based solutions and drawing logical conclusions, and decision-making. Another study by Ke et al., (2021) found that the application of socio-scientific issues (SSI) could improve students' critical thinking, decision-making, and reasoning skills. In analyzing and evaluating the problem-solving process, students are guided to engage in critical reflection on the investigative process they have conducted (Asmara, et al., 2023). This activity includes evaluating the strategies used, the effectiveness of the solutions developed, and the relevance and accuracy of the scientific information gathered (Schmidt, 1995). Students' reflections at this stage demonstrate active engagement in higher-order thinking, such as analyzing the validity of data, evaluating the appropriateness of methods, and considering the implications of their decisions (Uluçinar, 2023). Therefore, this stage significantly contributes to enhancing students' ability to critically evaluate and responsibly use scientific information based on evidence. However, according to Nafiati (2021), research and evaluation skills are included in the highest level of thinking in Anderson's Taxonomy, more complex than interpreting or explaining skills. Evaluating requires in-depth understanding, assessment of the relevance and validity of information, and critical thinking skills (Khikmah et al., 2024). As a result, this indicator showed the smallest gain compared to the others, likely due to the greater cognitive demands it places on students.

In addition to analyzing the category of scientific literacy improvement, this study also evaluated the level of significance of the improvement of students' scientific literacy after being treated. To find out whether the improvement was statistically significant, an inferential statistical test was used. However, before conducting the test, a normality test and a homogeneity test were first carried out and showed in Table 7.

Table 7
Recapitulation of Statistical Analysis Results of Pretest and Posttest of Scientific Literacy Test

No	Class		Normality Test		Homogeneity Test		Mann-Whitney Test	
			Sig.	Status	Sig.	Status	Sig.	Status
1	Pretest	Experiment	0.145	Normal	0,964	Homogen	0,896	Not Significant
		Control	0.268	Normal				
2	Postest	Experiment	0.005	Not Normal	0,022	Not Homogen	0,001	Significant
		Control	0.005	Not Normal				

The results of the normality test and the homogeneity test for the pretest in both the experimental and control classes showed that the data of the two classes were normally distributed and had homogeneous variances (Table 7). This shows that the initial abilities between the experimental and control groups were not statistically different (equivalent) (Novia et al., 2025). In contrast, the posttest data in both groups were found to be non-normally distributed and had non-homogeneous variances (Table 7). This condition indicates that the intervention of Problem-Based Learning (PBL) based on Socio-Scientific Issues (SSI) produced varying impacts across students. The difference in students' engagement levels, prior knowledge, and particularly students' learning styles likely contributed to the widened distribution of scores (Davis et al., 2020). Students have different preferences in how they process information; some learn better through visuals, others through hands-on activities or discussion-based exploration (Fathurrohman, 2012). As a result, some students were able to follow the PBL process more effectively, while others may have experienced difficulties in understanding and solving complex problems. Therefore, future research is recommended to integrate differentiated instruction into the implementation of the PBL-SSI model, so that all students, regardless of their initial ability and learning preferences, can participate effectively in the learning process (Sutrisno et al., 2023) and enhance their scientific competencies (Apriliandani et al., 2023), such as identifying and analyzing problems, interpreting data, formulating evidence-based solutions, drawing logical conclusions, and making informed decisions.

Based on Table 7, non-normal and non-homogeneous posttest data cause the inferential statistical test used, namely non-parametric tests including the Mann-Whitney test and the Wilcoxon test. The Wilcoxon Signed-Rank Test was conducted to see the differences in student learning outcomes between the pretest and posttest in each group (Novia et al., 2025). The results of the Wilcoxon test analysis are listed in Table 8.

Table 8
Wilcoxon Test Results

No	Class	Min	Max	Z	Sig.	Status
1	Experimental Class	35	95	-6.282	<0,001	Significant
2	Control Class	35	90	-6,516	<0,001	Significant

The results of the Mann-Whitney test indicate that there was no significant difference in students' initial abilities between the experimental and control groups before the treatment (Table 7), suggesting that both groups were in comparable conditions at the beginning of the study. However, after the treatment was implemented, a significant difference was found between the two groups, indicating the effectiveness of the intervention. Likewise, the Wilcoxon test showed that both the experimental and control groups experienced a significant increase in learning outcomes (Table 8). In accordance with research by Husniyyah et al. (2023) that there is a difference in the scientific literacy competency of students in the experimental and control classes. Yani et al. (2022) also obtained similar results that based on the independent sample t-test, the value obtained was 0.000 <0.05, which means that SSI-based learning has a significant effect on the scientific literacy, especially in the competency aspect. Another study, namely Lubis et al. (2022), found a significant difference in the results of the scientific literacy of students in the control class and the experimental class. Previous research, namely Sariningrum et al. (2018), showed that SSI-based learning provided a significant difference between the pretest and posttest results in the experimental class. Savery et al., (2001) stated that in the PBL learning process, students are encouraged to lead the investigation process, connect theory and practice, and apply the knowledge and skills they have to formulate appropriate solutions to the socio-scientific problems faced so that through these learning activities, students' scientific literacy competencies will develop, especially in ecosystem material which has many issues spread in society. The PBL-SSI learning helps students develop scientific behavior, make informed decisions related to socio-scientific problems, enhance their capacity to evaluate information, and engage in discussions about sociotechnical controversies relevant to their lives (Sadler et al., 2009). Scientific literacy also contributes to the development of life skills, as it involves the application of scientific concepts when individuals make decisions regarding situations or problems related to science (Sulistina et al., 2024). Based on the findings of these three studies, it can be concluded that SSI-based learning has the potential to enhance students' scientific literacy.

3. Student Reflection

Student reflection is used to determine the impact or effectiveness of the learning that is applied, seen from the student's perspective (student perception after the learning process). The recapitulation of student reflection results based on the three indicators of the PISA 2025 scientific literacy is listed in Table 9.

Table 9
Recapitulation of Student Reflection Results in Each Indicator

No	Indicators Scientific literacy	Percentage	Category
1	Explain phenomena scientifically	76%	Good
2	Construct and evaluate designs for scientific enquiry and interpret scientific data and evidencse critically	72%	Good
3	Research, evaluate and use scientific information for decision making and action	77%	Good

The analysis of students' reflections indicated that they responded positively to the learning process. In the Explain phenomena scientifically indicator, students reported a positive experience, with an average response of 76% in the "Good" category. This suggests that students felt confident in identifying and explaining natural phenomena scientifically, as well as in applying scientific knowledge to solve real-life problems (Putri et al., 2025). For the Construct and evaluate designs for scientific inquiry and interpret scientific data and evidence critically indicator, students also gave a positive response, with an average of 72% categorized as "Good". This indicates that students felt capable of formulating scientific questions, designing solutions, evaluating outcomes, and drawing conclusions based on scientific data (Uluçinar, 2023). Meanwhile, the Research, evaluation, and use of scientific information for decision-making and action indicator received the highest positive response, with an average of 77% in the "Good" category. This shows that students perceived themselves as being able to utilize scientific information to support decision-making during the learning process (Khikmah et al., 2024).

The results of student reflection showed a relatively lower response to the indicators of building and evaluating scientific research designs and interpreting data and scientific evidence, compared to the other two indicators. This finding is not entirely in line with the results of the N-Gain analysis, which showed that this indicator had the highest increase. This difference shows that although cognitively students have increased their ability to compile research designs and interpret data, students have not fully realized this achievement or felt confident in the process. The complexity of the scientific process involved in this indicator, such as data analysis and research design, is considered quite challenging by students, especially because of the limited experience of students in drawing conclusions from the data presented and carrying out scientific activities directly. Research by Samosir et al., (2024) shows that many students feel and have difficulty understanding basic concepts such as tables, diagrams, and graphs, which has an impact on critical thinking skills in processing and utilizing information.

CONCLUSION

The implementation of learning using the Problem-Based Learning model based on Socio-Scientific Issues on ecosystem material was carried out very well, where all stages of learning, from the introduction, core activities, to the closing, could be carried out consistently and optimally, especially at the second meeting, which showed an increase in implementation. The effectiveness of this learning is also reflected in the results of the students' scientific literacy test, which was analyzed through the Wilcoxon and Mann-Whitney tests, showing a significant increase. Based on the N-gain results, the increase is in the moderate category. In addition, the results of student reflections strengthen these findings, where students respond positively to the learning experience. Overall, these findings indicate that the application of the PBL-SSI model is effective in improving students' scientific literacy, including understanding scientific phenomena, designing data-based solutions, and using scientific information in decision making and action on ecosystem material. However, the scope of research using the Problem-Based Learning model based on Socio-Scientific Issues was only carried out on ecosystem material and in the context of one school with certain characteristics (small sample) so that the generalization of the results is limited.

REFERENCES

Apriliandani, F., & Maryani, I. (2023). *Efektivitas Pembelajaran Diferensiasi Berbasis Gaya Belajar Siswa Kelas IV Untuk Meningkatkan Kemampuan Pemecahan Masalah*. *10*(1), 1–8. http://journal.uad.ac.id/index.php/JPSD

Arding, N. I., & Atun, S. (2020). Analysis of Junior High School Students ' Scientific Literacy On Simple Effort and Aircraft for Everyday Life. *Journal of Physics: Conference Series*. https://doi.org/10.1088/1742%0A6596/1440/1/012095

Arends, R. I. (2008). Learning to Teach 7th Ed. McGraw-Hill.

Ariska, I., & Rosana, D. (2020). Analysis of Junior High School Scientific Literacy Skills : Domain Competence On Vibrations, Waves and Sound Materials. *Journal of Physics: Conference Series*, *17*. https://doi.org/10.1088/1742 6596/1440/1/012094

Arikunto, S. (2012). Manajemen Penelitian. Rineka Cipta.

Asmara, M. P., & Septiana, M. P. (2023). *Model Pembelajaran Berkonteks Masalah* (1st ed.). Azka Pustaka.

Azizah, D. N. (2021). *Pengaruh Model Pembelajaran Problem Based Learning Berkonteks Socio Scientific Issues Terhadap Kemampuan Literasi Sains Siswa pada Materi Asam Basa*. Skripsi, Universitas Islam Negeri Syarif Hidayatullah Jakarta, Indonesia.

Barrows, H. S. (1986). A taxonomy of problem-based learning methods. *Medical Education*, 20, 481–486.

Berland, L. K., & Reiser, B. (2008). Making Sense of Argumentation and Explanation. *Science Education*, *93(1)*, 26–55. https://doi.org/10.1002/sce.20286

Davis, S. K., Edwards, R. L., & Hadwin, A. F. (2020). Using Prior Knowledge and Student Engagement to Understand Student Performance in an Undergraduate Learning-to-Learn Course Using Prior Knowledge and Student Engagement to Understand Stude. *International Journal for the Scholarship of Teaching and Learning 14*(2). https://doi.org/10.20429/ijsotl.2020.140208

Fauziah, N., Hakim, A., & Andayani, Y. (2019). Meningkatkan Literasi Sains Peserta Didik Melalui Pembelajaran Berbasis Masalah Berorientasi Green Chemistry pada Materi Laju Reaksi. Jurnal Pijar MIPA, 14(2), 31-35. https://doi.org/10.29303/jpm.v14i2.1203

Fathurrohman, M., & Sutistyorini, M. (2012). *Belajar & Pembelajaran* (1st ed.). Teras.

Fibonacci, & Sudarmin. (2014). Development fun-chem learning materials integrated socio-science issues to increase studentsscientific literacy. *International Journal of Science and Research*, 11(3), 708- 713.

Fuadi, H., Robbia, A. Z., Jamaluddin, J., & Jufri, A. W. (2020). Analisis Faktor Penyebab Rendahnya Kemampuan Literasi Sains Peserta Didik. *Jurnal Ilmiah Profesi Pendidikan*, *5*(2), 108–116. https://doi.org/10.29303/jipp.v5i2.122

Graaff, E. D. E. (2003). Characteristics of Problem-Based Learning. I*nt. J. Engng Ed*, *19*(5), 657-662

Hanifha, S., Erna, M., Noer, A. M., & Talib, C. A. (2023). Socioscientific Issue-Based Undergraduate Student Worksheets on Scientific Literacy and Environmental Awareness. *Jurnal Pendidikan IPA Indonesia*, *12*(4), 504–513. https://doi.org/10.15294/jpii.v12i4.45817

Hestiana, & Rosana, D. (2020). The Effect of Problem Based Learning Based Sosio-Scientific Issues on Scientific Literacy and Problem-Solving Skills of Junior High School Students. *Journal of Science Education Research*, *4*(1), 15–21. https://doi.org/10.21831/jser.v4i1.34234

Hidayat, A. T., & Hidayati, S. N. (2024). Peningkatan Literasi Sains Siswa Berbantuan Lkpd Berorientasi Socio Scientific Issues (Ssi). *EDUPROXIMA : Jurnal Ilmiah Pendidikan IPA*, *6*(1), 57–63. https://doi.org/10.29100/.v6i1.4378

Husniyyah, A. A., Purnomo, T., & Budiyanto, M. (2023). Scientific Literacy Improvement Using Socio-Scientific Issues Learning. *IJORER: International Journal of Recent Educational Research*, *4*(4), 447–456. https://doi.org/10.46245/ijorer.v4i4.303

Isti, S., Wida, T., Amarta, D., & Prabowo, C. A. (2020). *Analisis kemampuan literasi sains siswa sma pada pembelajaran biologi menggunakan noslit. Jurnal Bioeduin, 10(1),* 27-34. https://doi.org/10.15575/bioeduin.v10i1.8141

Jaedun, A. (2011). *Metodologi Penelitian Eksperimen.* LPMP UNY.

Ke, L., Sadler, T. D., Zangori, L., & Friedrichsen, P. (2021). Developing and using multiple models to promote scientific literacy in the context of socio-scientific issues. *Science & Education, 30*(4), 589–607. https://doi.org/10.1007/s11191-021-00206-1

Khikmah, M. U., Sudibyo, E., & Mursyidah, R. (2024). Efektivitas Pendekatan Socio-Scientific Issues (SSI) Pada Materi Pencemaran Lingkungan Untuk Meningkatkan Literasi Sains Siswa SMP. *EKSAKTA : Jurnal Penelitian Dan Pembelajaran MIPA*, *9(2)*, 221–227. http://dx.doi.org/10.31604/eksakta.v9i2.221–227

Lubis, S. P. W., Suryadarma, I. G. P., Paidi, & Yanto, B. E. (2022). The Effectiveness of Problem-based learning with Local Wisdom oriented to Socio-Scientific Issues. *International Journal of Instruction*, *15*(2), 455–472. https://doi.org/10.29333/iji.2022.15225a

Muñoz, J., Zueco, E., Sánchez, E., & Salillas, E. (2023). Science Skills Development through Problem-Based Learning in Secondary Education. *Education Sciences*, *13*(11). https://doi.org/10.3390/educsci13111096

Nafiati, D. (2021). Revisi taksonomi Bloom: Kognitif, afektif, dan psikomotorik. *Humanika*, *21(2)*, 151–172. http://dx.doi.org/10.21831/hum.v21i2.29252

Nainggolan, V. A., Pramana, R., & Pudji, S. (2021). Bryophyta: Improving students scientific literacy through problem-based learning. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *7*(1), 71–82. https://doi.org/ 10.22219/jpbi.v7i1.15220%0A

Nasirun, M., Yulidesni, & Daryati, M. E. (2019). Studi Kemampuan Mengajar Peer Teaching Mahasiswa Semester V Program Studi S1 Pendidikan Guru Paud Tahun Ajaran 2018/2019 Fkip Universitas Bengkulu. *Jurnal Tunas Siliwangi*, *5*(2), 73–83. https://doi.org/10.37058/jspendidikan.v5i2.944

Novia, D., Husaeni, A., Gintara, A. R., & Nabila, G. F. (2025). *Mengungkap Pentingnya Uji Normalitas dan Homogenitas dalam Penelitian : Studi Kasus dan Aplikasinya*. *9*(2011), 829–839. https://jptam.org/index.php/jptam/article/view/24268/16503

Osborne, J., White, P., Aleixandre, M. J., Cutler, M., Leach, D., et al. (2023). *PISA 2025 Scientific literacy (Draft)*. Oxford University Press.

Permanasari, A., Sariningrum, A., Rubini, B., & Ardianto, D. (2021). Improving Students' Scientific Literacy Through Science Learning with Socio Scientific Issues (SSI). *Proceedings of the 5th Asian Education Symposium 2020 (AES 2020)*, *566*, 323–327. https://doi.org/10.2991/assehr.k.210715.068

Permatasari, N. (2022). Identifikasi Kompetensi Literasi Sains Peserta Didik Pada Pelajaran Ilmu Pengetahuan Alam di SMP Negeri 43 Rejang Lebong. *Jurnal Didaktika Pendidikan Dasar*, *6*(1), 23–46. https://doi.org/10.26811/didaktika.v6i1.799

Purwandari, A., Deaningtyas, S. A., Faradillah, N. I., Putrikundia, S. A., & Sulistina, O. (2020). Peran pendekatan Socio-Scientific Issue (SSI) dalam meningkatkan scientific literacy pada pembelajaran

kimia. *UNESA Journal of Chemical Education*, *13*(2), 118–128. https://doi.org/10.26740/ujced.v13n2.p118-128
Putri, P.D., Tukiran, & Nasrudin, H. (2018). The Effectiveness Of Problem-Based Learning (PBL) Models Based On Socio-Scientific Issues (SSI) To Improve The Scientific Literacy Ability. *Jurnal Penelitian Pendidikan Sains*, *7*(2), 1519–1524. https://doi.org/10.26740/jpps.v7n2.p1519-1524
Puteri, L. H. (2018). The Apperception Approach for Stimulating Student Learning Motivation. *International Journal of Education, Training, and Learning*, *2*(1), 7–12. https://doi.org/10.33094/6.2017.2018.21.7.12
Putri, P. N., Rachmadiarti, F., Purnomo, T., & Satriawan, M. (2025). *Measuring Scientific Literacy o f Students ' Through Environmental Issues Based on PISA 2025 Science Framework*. *11*(3), 44–53. https://doi.org/10.29303/jppipa.v11i3.10413
Putriyani, E. (2023). Penerapan Model Problem Based Learning (PBL) terhadap Keterampilan Berpikir Kritis dan Literasi Sains Siswa pada Pembelajaran IPA Terpadu Materi Ekosistem Siswa Kelas VII SMP Negeri 1 Kadipaten Tasikmalaya. *Naturalistic: Jurnal Kajian Dan Penelitian Pendidikan Dan Pembelajaran*, *8*(2), 267–280. https://doi.org/10.35568/naturalistic.v8i2.3984
Rahayu, I. D., Permanasari, A., & Heliawati, L. (2022). The Effectiveness of Socioscientific Issue-Based Petroleum Materials Integrated with The Elsmawar Website on Students' Scientific Literacy. *Journal of Innovation in Educational and Cultural Research*, *3*(2), 279–286. https://doi.org/10.46843/jiecr.v3i2.118
Ramli, M., Saridewi, N., Rifki, A., Studi, P., Kimia, P., Negeri, U. I., & Jakarta, S. H. (2021). *Analysing Traditional Islamic Boarding School Students ' Scientific Literacy Using Pisa Framework*. *6*(1), 31–39. http://journal.unesa.ac.id/index.php/jppipa
Rohmawati, E., Widodo, W., & Agustini, R. (2018). Membangun Kemampuan Literasi Sains Siswa Melalui Pembelajaran Berkonteks Socio-Scientific Issues Berbantuan Media Weblog. *Jurnal Penelitian Pendidikan IPA*, *3*(1), 8-14. https://doi.org/10.26740/jppipa.v3n1.p8-14
Rohmaya, N. (2020). Peningkatan Literasi Sains Siswa Melalui Pembelajaran IPA Berbasis *Socioscientific Issues* (SSI). *Jurnal Pendidikan MIPA*, 12(2), 723–731. https://doi.org/10.37630/jpm.v12i2.553
Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, *46*(8), 909–921. https://doi.org/10.1002/tea.20327
Saija, M., Rahayu, S., Fajaroh, F., & Sumari. (2022). Enhancement of High School Students' Scientific Literacy Using Local-Socioscientific Issues in Oe3C Instructional Strategies. *Jurnal Pendidikan IPA Indonesia*, *11*(1), 11–23. https://doi.org/10.15294/jpii.v11i1.33341
Samosir, E. D., Ansya, Y. A., Ade, N. F., Naibaho, Y., Rahmadani, & Sitoris, I. (2024). Analisis Kesulitan Siswa Dalam Mempelajari Materi Pengolahan. *Jurnal Guru Kita PGSD*, 9(1), 105-111. https://doi.org/10.24114/jgk.v9i1.64306
Sariningrum, A., Rubini, B., & Ardianto, D. (2018). Pembelajaran Berbasis Masalah (PBL) Dengan Konteks Socioscientific Issues Pada Materi Pemanasan Global Untuk Meningkatkan Literasi Sains Siswa. *Journal of Science Education And Practice*, *2*(2), 27–43. https://journal.unpak.ac.id/index.php/jsep%0A35
Savery, J. R., & Duffy, T. M. (2001). Problem Based Learning: An instructional model and its constructivist literacy. *CRLT Technical Report,* 16(1).
Schmidt, H. G. (1995). Problem Based Learning: An introduction. *Instructional Science*, *22*, 247–250. https://www.jstor.org/stable/23369986
Subiantoro, N.A. & Ariyanti, S. (2013). Pembelajaran Materi Ekosistem Dengan *S*ocio-Scientific Issues Dan Pengaruhnya Terhadap Reflective Judgment Siswa. *Jurnal Pendidikan IPA Indonesia*, *2*(1), 41–47. https://doi.org/10.15294/jpii.v2i1.2508
Sulistina, O., Purwandari, A., Deaningtyas, S. A., Putrikundia, S. A., & Faradillah, N. I. (2024). Peran Pendekatan Socio-Scientific Issue (Ssi) Dalam Meningkatkan Scientific Literacy Pada Pembelajaran Kimia. *UNESA Journal of Chemical Education*, *13*(2), 118–128. https://doi.org/10.26740/ujced.v13n2.p118-128
Sutrisno, L. T., Muhtar, T., & Herlambang, Y. T. (2023). Efektivitas Pembelajaran Berdiferensiasi Sebagai Sebuah Pendekatan untuk Kemerdekaan. *DWIJA CENDEKIA: Jurnal Riset Pedagogik*, *7*(2). https://doi.org/10.20961/jdc.v7i2.76475
Thomson, S., Hillman, K., & Botroli, L. De. (2013). *A Teacher's Guide to PISA Scientific Literacy*. ACER

Press.
Toharudin, Hendrawati, & Rustaman, A. (2011). *Membangun Literasi Sains Peserta Didik*. Humaniora.
Uluçinar, 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
Yani, J., & Afrianis, N. (2022). Analysis of student scientific literacy using the socio-scientific issues (SSI) approach on reaction rate. *Jurnal Pendidikan Kimia*, *14*(1), 19–27. https://doi.org/10.24114/jpkim.v14i1.32665
Yenni, R., Hernani, & Widodo, A. (2017). The implementation of integrated science teaching materials based socio-scientific issues to improve students scientific literacy for environmental pollution theme. *AIP Conference Proceedings*, 16, 12-40. https://doi.org/10.1063/1.4983970
Yolida, B. (2021). Problem Based Learning model using vee diagrams on students' scientific literacy of environmental pollution material. *JPBIO (Jurnal Pendidikan Biologi)*, *6*(1), 55–63. http://jurnal.stkippersada.ac.id/jurnal/index.php/JBIO/index%0AProblem