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# Increasing Students' Scientific Literacy Competence Through A Stem-Based PjBL Learning Model: A Case Study of an Ecosystem Project

Fitri Yuliawati[1*], Endang Sulistyowati[1], Anita Ekantini[1], Inggit Dyaning Wijayanti[1]

[1] Madrasah Ibtidaiyah Teacher Education, UIN Sunan Kalijaga Yogyakarta, Indonesia.

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Corresponding Author:
Fitri Yuliawati
fitri.yuliawati@uin-suka.ac.id

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**Abstract:** Scientific literacy has an important role in equipping individuals to be sensitive to the environment and actively participate in making decisions regarding existing environmental issues. This research aims to test the effectiveness of the STEM-based Project-Based Learning (PjBL) learning model in increasing the scientific literacy of PGMI students in science courses. This research uses an experimental method with a one group pretest-posttest design. The research subjects were 41 students selected using cluster random sampling technique. The instruments used in this research include a scientific literacy test instrument and an observation sheet on the implementation of PjBL-STEM learning. The findings of this research show that learning through PjBL-STEM on Ecosystem material facilitates students in solving existing environmental problems in the form of STEM-based projects. The results of the T-Paired test have a sig.2-tailed value of 0.000<0.05, indicating that there is a significant difference in the scientific literacy results of PGMI students in science courses. Based on the N-Gain analysis, a score of 0.5 shows that the STEM-based PjBL learning model is effective in increasing the scientific literacy of students in the medium category.

**Keywords:** Project-based learning; Scientific literacy; STEM

## Introduction

In an era of rapid technological and scientific development, it is important for students to have strong scientific literacy competencies. Scientific literacy is the ability to collect, analyze and conclude information logically and critically in the context of science (Astuti et al., 2020; Ellahi et al., 2019). Scientific literacy competency is currently considered the main goal for improving human resources in the 21st century. The most important competency of graduates of the Madrasah Ibtidaiyah Teacher Education (PGMI) study program is being able to become educators and facilitators who have soft skills and hard skills that can be utilized by students at the elementary/MI education level (AShernoff et al., 2017).

In the 21st century, prospective teachers must master the 4C abilities, namely communication skills, collaboration skills, critical thinking skills and solving problems, and creativity and innovation (Rachmadtullah et al., 2020). According to Marshall et al. (2020), at any time an educator's duties can change according to the needs of the times. However, every educator is required to be able to overcome problems professionally and be ready to face various types of obstacles that will be faced later (Rahman et al., 2021). The concept of 21st century learning encourages students to develop core knowledge of academic subjects, higher order thinking skills, and learning skills in order to thrive in a rapidly changing world (Tan et al., 2017).

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Educators play an important role in determining the right learning design according to student needs (Kelley & Knowles, 2016). It is anticipated that 21st century education will develop human resources that have various 21st century competencies, including scientific literacy (Menggo et al., 2019; Rios et al., 2020). Scientific literacy competencies or scientific reasoning competencies are needed for Madrasah Ibtidaiyah Teacher Education (PGMI) students (Akcanca & Ozsevgec, 2017; Taufiq & Rokhman, 2020). The scientific literacy competencies that students must master are aspects of scientific literacy, ability to solve problems, science content, and mastery of science process skills. According to PISA, scientific literacy competencies consist of three, namely understanding scientific phenomena, evaluating and designing scientific investigations, and interpreting scientific data and evidence (OECD, 2019). Scientific literacy is not only related to science, but is also related to humans' ability to socialize in society in making decisions and acting responsibly (Suwono et al., 2022). In addition to having knowledge of scientific concepts and theories, students also need knowledge of general procedures and practices related to scientific investigation.

According to NCREL (The North Central Regional Educational Laboratory) (2003), students who have scientific literacy have the ability to master and understand scientific concepts and processes needed when interacting with society in the digital era. Students can ask questions, get, or decide answers to questions that will be found in real life. In addition, students can identify scientific issues at both local and national levels and provide scientific and technological information. Students can also assess the quality of scientific information based on the sources and methods used to produce it. Apart from that, students must also be able to present and evaluate arguments based on existing evidence and create appropriate debate summaries (Lemke, 2002).

Initial observations made showed that in basic science learning, PGMI students did not understand the natural phenomena around them, were less able to relate the material to everyday contexts, and were less skilled in designing and carrying out experiments. Based on these facts, it is known that students' scientific literacy abilities are low. Scientific literacy is the ability to engage with issues related to science and scientific ideas as a reflective citizen (OECD, 2019). It is feared that the low scientific literacy abilities of PGMI students will result in misinterpretation of concepts in elementary school students, resulting in a decline in the quality and learning outcomes both in terms of knowledge (cognitive), attitudes and values (affective) and skills (psychomotor). Quoting from research Nuraina et al. (2023) students with a percentage of 33.44% experienced a miss conception caused by many factors, one of which was the way the teacher taught. PGMI students as prospective SD/MI teachers as science teaching staff in elementary schools must have adequate science knowledge (theory and practice in science learning) so that students have better abilities in studying science, especially those related to basic science concepts. Apart from mastering basic science concepts theoretically, prospective teachers must also have good knowledge (science theory) regarding the application of basic science concepts theory in science practicum.

One learning model that can improve scientific literacy is the project-based learning (PjBL) model. PjBL is a model that requires students to participate directly in a project, making students interested in learning by solving problems, collecting data, discussing, and presenting the results of the projects they have carried out (Miller et al., 2021). Another opinion from Hart, Project-based learning is known to be effective for facilitating the acquisition and retention of knowledge, supporting the development of important real-world skills such as solving complex problems, thinking critically, analyzing and evaluating information, collaborating, and communicating effectively and for developing flexible knowledge (Hart, 2019).

The advantages of the PjBL approach in teaching are enormous (Holm, 2011): (1) Students develop motivation and take responsibility for their learning; (2) They create their knowledge and understanding in an integrative manner; (3) Knowledge is sustainable over a long period of time; (4) Students learn to communicate through problem solving; (5) They experience a variety of learning tasks; and (6) They get responses to their learning needs (Goldstein, 2016). In this research, the PjBL learning model developed emphasizes integration between the PjBL model and the STEM approach, so that the syntax for the implementation and application of the PjBL model will be the result of integration between the STEM-based PjBL learning model using Backward Design (BD).

To develop scientific literacy competencies, students need to experience a learning process that is integrated with Science, Technology, Engineering, and Mathematics (Kelley & Knowles, 2016; Shernoff et al., 2017). Science, Technology, Engineering, and Mathematics (STEM) is believed to be able to contribute to the development of 21st century skills (Altan & Ercan, 2016). Through STEM, it is hoped that students will be able to develop their scientific literacy competencies to compete in the future and be able to solve all problems by utilizing technology (English, 2016; Kelley & Knowles, 2016; Wahono et al., 2020). The integration of STEM in teaching and learning can be carried out at all levels of education, from elementary school to university (Erdogan et al., 2016). In addition, STEM-PjBL has a significant impact in developing students' abilities (Beier et al., 2019).

The process of implementing learning with a STEM framework has not been carried out optimally, especially Basic Science learning in the Madrasah Ibtidaiyah Teacher Education Study Program (PGMI) UIN Sunan Kalijaga Yogyakarta. From the Semester Learning Plan Documentation Study, it can be seen that the learning outcomes in science courses have not yet internalized the components of students' scientific reasoning competencies. Apart from the RPS, other learning components such as teaching materials and assessment instruments have also not shown any internalization of the scientific literacy competency component. Researchers have conducted a preliminary study by observing the learning process, interviewing lecturers who teach science subjects at the PGMI Study Program and obtaining data related to the learning model carried out.

Based on this background, it is necessary to carry out in-depth research regarding the effectiveness of implementing the STEM-based PjBL model in improving students' scientific reasoning competence. This is especially important for science courses in the PGMI Study Program which have not been able to implement the STEM-based PjBL model optimally.

In research conducted by Candra (Rini et al., 2021) it is said that students' scientific literacy abilities in the competency aspect have not shown good and satisfactory results. By rearranging the scope of lecture material and using appropriate models, scientific literacy skills can be improved in aspects of student competency. Research conducted by Fazilla (2016) also shows that students' scientific literacy skills still need to be improved. For this reason, arrangements are made regarding the scope of lectures, the lecture process, the selection of appropriate media and models to increase students' scientific literacy. Not much different, research conducted by Hendri et al. (2019) found that students' scientific literacy, especially in Papua, is still low. Similar research was also conducted by Farida et al. (2022) in this research showing that the use of a project based learning model can improve students' numerical abilities. In research conducted by Sakti et al. (2021) also applied a project based learning model to improve students' scientific literacy skills in science learning, showing that the average student literacy ability increased in three aspects, namely content, process and context.

From the results of the study found, the novelty of this research lies in the need for students to improve reasoning competence by using a STEM-based project-based learning model. More in-depth studies can provide a better understanding of the benefits, challenges, and development potential of this learning model. In this context, this research aims to investigate the effectiveness of the STEM-based PjBL learning model on students' level of scientific reasoning competency. This research will provide valuable insights for educators and policy makers in designing more effective learning strategies to develop students' scientific reasoning abilities. In addition, this research can also contribute to scientific research in the field of STEM education and relevant curriculum development.

## Method

The approach used in this research is a quantitative approach with a quasi-experimental method. Quasi-experiment is experimental research, but not all variables that influence the experiment can be controlled (Pramesti et al., 2019). The design of this research is one group pretest-posttest.

**Table 1.** Research design
(Sugiyono, 2016)

| Pretest | Treatment | Posttest |
|---|---|---|
| $O_1$ | X | $O_2$ |

The population of this study was third semester PGMI UIN Sunan Kalijaga students consisting of three classes, namely A, B, and C. The sample was selected using a cluster random sampling technique and 41 students were selected for class A.

**Table 2.** PjBL-STEM Model Observation Sheet Grid

| Phase | Meeting |
|---|---|
| Start With the Essential Question | 1 |
| Design a Plan for the Project | 1 |
| Create a Schedule | 1 |
| Monitor the Students and the Progress of the Project | 2, 3,4,5 |
| Assess the Outcome | 6 |
| Evaluate the Experience | 7 |

**Table 3.** Scientific Literacy Test Grid

| Scientific Literacy Indicators | Question Number |
|---|---|
| Explain phenomena scientifically | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 |
| Evaluate and design scientific investigations | 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25 |
| Interpret data and use scientific evidence | 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40 |

The instruments used in this research include observation sheets and test instruments. The observation sheet instrument is used to determine the implementation of learning using the PjBL-STEM model. The observation statement items in this study consisted of 20 statements. The instrument test is used to determine students' scientific literacy abilities. The test instrument consists of 40 scientific literacy questions in multiple choice form. Each instrument was validated by two experts. The PjBL-STEM observation sheet instrument grid can be seen in Table 2 and the scientific literacy test instrument grid can be seen in Table 3.

Analysis of learning implementation in the form of implementation percentage. The learning implementation formula can be seen in Equation 1.

$$\% \text{ implementation } = \frac{\sum aspects\ of\ learning\ carried\ out}{\sum all\ aspects} \text{x } 100\% \quad (1)$$

The quantitative data on the percentage of learning implementation obtained was then converted into qualitative data using the criteria for this learning implementation category in the form of percentages which are presented in Table 4. Based on Table 4, it can be seen that the learning implemented implements the PjBL-STEM model well if the percentage of implementation is above 60%.

**Table 4.** Percentage and Categories of Learning Implementation (Widoyoko, 2016)

| Percentage | Category |
|---|---|
| >80 | Very good |
| >60-80 | Good |
| >40-60 | Enough |
| >20-40 | Less |
| ≤20 | Very less |

Hypothesis test data analysis using t-paired test and n-gain. Previously, a prerequisite hypothesis test was carried out which included a normality test. After the prerequisite hypothesis test is fulfilled and the data is declared normal, the hypothesis test is then carried out, namely the t-paired test. The t-paired test was chosen because the data is paired data from the same population. Based on the results of the t-paired test, if the sig.2-tailed value is <0.05, it can be concluded that there is a difference in the character of caring for the environment between the pretest and posttest. Next, an n-gain test was carried out to see the effectiveness of the PjBL-STEM model on environmental literacy. The N-Gain formula is in Formula 2. The hypotheses in this research are as follows.

$H_0$: The PjBL-STEM model is not effective in increasing students' scientific literacy

$H_a$: The PjBL-STEM model is effective in increasing students' scientific literacy

$$< g > = \frac{S_{post} - S_{pre}}{S_{m\ ideal} - S_{pre}} \quad (2)$$

**Table 5.** N-Gain Effectiveness Criteria (Hake, 1999)

| Normalized Gain Value | Effectiveness Criteria |
|---|---|
| 0.7 ≤g< 1.0 | High |
| 0.3 <g< 0.7 | Medium |
| 0 <g< 0.3 | Low |

Description: g = Normalized mean gain score; $S_{post}$ = The average final test score obtained by students; $S_{pre}$ = The average initial test score obtained by students; $S_{m\ ideal}$ = Ideal maximum score.

The n-gain criteria for the effectiveness of the PjBL-STEM model in increasing student scientific literacy are shown in Table 5.

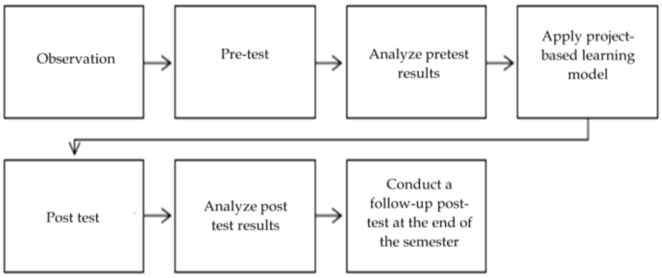


**Figure 1.** Research process flow

## Result and Discussion

This research was conducted in the PGMI UIN Sunan Kalijaga study program for third semester students. The focus of this research was to look at the scientific literacy abilities of PGMI students in the Science course on Ecosystems. This research consists of three stages, namely pretest, treatment, and posttest. Before conducting the research, all instruments used in this research were validated constructively and empirically. Construct validation was carried out by two expert lecturers, namely the evaluation lecturer and the science lecturer. After being declared valid by the expert, empirical validation is then carried out. Empirical validation was carried out in the field, namely on non-sample third semester PGMI students (ie in class B). The results of the empirical test analysis on the test instrument can be seen in Table 6.

**Table 6.** Question Item Validity Test Results

| Question number | Sig. value | Result | Conclusion |
|---|---|---|---|
| 1 | 0.267 | Invalid | Not used |
| 2 | 0.035 | Valid | Used |
| 3 | 0.005 | Valid | Used |
| 4 | 0.136 | Invalid | Not used |
| 5 | 0.005 | Valid | Used |
| 6 | 0.678 | Invalid | Not used |
| 7 | 0.000 | Valid | Used |
| 8 | 0.000 | Valid | Used |
| 9 | 0.000 | Valid | Used |
| 10 | 0.000 | Valid | Used |
| 11 | 0.298 | Invalid | Not used |
| 12 | 0.062 | Invalid | Not used |
| 13 | 0.815 | Invalid | Not used |
| 14 | 0.018 | Valid | Used |
| 15 | 0.000 | Valid | Used |
| 16 | 0.001 | Valid | Used |
| 17 | 0.002 | Valid | Used |

| Question number | Sig. value | Result | Conclusion |
|---|---|---|---|
| 18 | 0.202 | Invalid | Not used |
| 19 | 0.094 | Invalid | Not used |
| 20 | 0.011 | Valid | Used |
| 21 | 0.002 | Valid | Used |
| 22 | 0.006 | Valid | Used |
| 23 | 0.014 | Valid | Used |
| 24 | 0.069 | Invalid | Not used |
| 25 | 0.000 | Valid | Used |
| 26 | 0.278 | Invalid | Not used |
| 27 | 0.452 | Invalid | Not used |
| 28 | 0.000 | Valid | Used |
| 29 | 0.011 | Valid | Used |
| 30 | 0.003 | Valid | Used |
| 31 | 0.004 | Valid | Used |
| 32 | 0.032 | Valid | Used |
| 33 | 0.000 | Valid | Used |
| 34 | 0.028 | Valid | Used |
| 35 | 0.000 | Valid | Used |
| 36 | 0.000 | Valid | Used |
| 37 | 0.000 | Valid | Used |
| 38 | 0.000 | Valid | Used |
| 39 | 0.022 | Valid | Used |
| 40 | 0.000 | Valid | Used |

Based on the results of the analysis of the questions carried out with the help of the SPSS program, it was found that out of 40 questions that were valid and suitable for use, there were 29 questions. After all instruments are declared valid, they can then be used for the main field test.

**Figure 2.** Pretest implementation

The initial activity of this research is a pretest, namely a test to reveal students' initial abilities regarding their scientific literacy. The pretest instrument is in the form of multiple choice scientific literacy questions with a total of 29 items. The Prestet results can be seen in Table 9. From table 9, it is known that the initial scientific literacy abilities of PGMI students are still low.

The second stage of this research is intervention. In this research, the intervention was carried out using a STEM-based PjBL learning model by creating a Rice Field Ecosystem project. The learning outcomes for this course are "Students are able to understand the scope and depth of Ecosystem material through questions and answers, logical, critical, systematic, innovative and responsible discussions." Learning objectives can be seen in Table 7. The intervention was given to research subjects in seven meetings with a duration of 50 minutes each meeting. Students are given the freedom to determine projects according to the rice field ecosystem topics they find in the field.

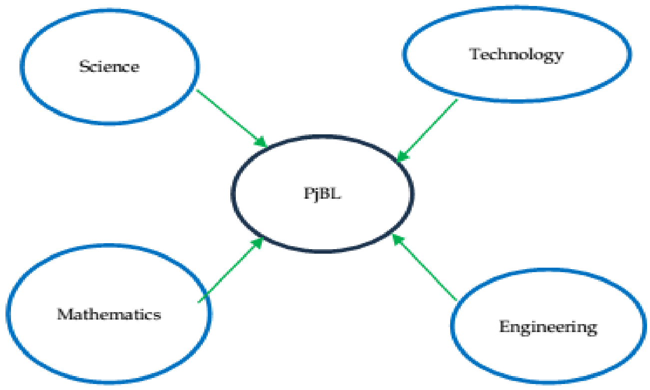


**Figure 3.** Integration of the PjBL model with STEM (Amri et al., 2020)

Figure 3 shows STEM in the PjBL Model, namely integrating the STEM approach into the PjBL model. Learning is carried out by following the PjBL model syntax where the project contains STEM aspects.

**Table 7.** Learning Objectives

| Learning Objectives |
|---|
| Explain the level of organization of life in an ecosystem |
| Explain the constituent components of an ecosystem |
| Explain the types of interactions in ecosystems |
| Explain food chains and food networks in ecosystems |
| Explain the flow of energy and cycles of matter in ecosystems |

The intervention was carried out over seven meetings with each meeting lasting 50 minutes. The schedule for this activity can be seen in Table 8.

The first meeting was to understand the phenomena that exist in the rice field ecosystem. After students understand the problems or issues that exist, then in groups students prepare a project plan related to the Rice Field Ecosystem. After they design the project plan, they continue with preparing a schedule for completing the project. The preparation of this product certainly involves STEM elements in it. Science learning is very appropriate if implemented using the PjBL model which is integrated with STEM. This is in accordance with the demands of current developments, technology-based and in accordance with the abilities that must be mastered by prospective elementary education teacher students in the 21st century (Purwanti et al., 2022; Rohman et al., 2021).

**Figure 4.** Implementation of the PjBL learning model

**Table 8.** Project Implementation Schedule

| Meeting | Activity |
|---|---|
| 1 | Understand existing environmental phenomena/issues<br>Develop a strategy/project form<br>List tool and material requirements for the project |
| 2 | Presentation of project progress |
| 3 | |
| 4 | |
| 5 | |
| 6 | Product assessment, namely product exhibition for each group |
| 7 | Evaluation of project implementation |

The second to fifth meetings are filled with reporting and presentations of project progress from students. In this activity, each group reports and shows the progress of their project. The group presenting will receive input from the lecturer and also from other groups, so that it can be used to improve the product they have prepared. At the sixth meeting, a product assessment was held, namely an exhibition of each group's products. Then the seventh meeting is to evaluate the implementation of the project being carried out.

**Figure 5.** Posttest implementation

During the learning process, observations were made of the implementation of PjBL-STEM. Based on the analysis results, it is known that the implementation of the PjBL-STEM model is 90%. This shows that the overall syntax of PjBL-STEM is implemented well.

The stage after implementing the treatment is a posttest to measure students' scientific literacy abilities after using the PjBL-STEM model. The posttest questions are the same as the pretest questions, the aim is that the increase in scientific literacy scores can be measured more easily.

**Table 9.** Scientific Literacy Score

| Category | Pretest | Posttest |
|---|---|---|
| The Highest Sore | 73 | 97 |
| The Lowest Score | 44 | 55 |
| Mean | 60 | 85 |
| Standard Deviation | 9.01 | 13.67 |

Figure 6 shows that the scientific literacy score after being given intervention with the PjBL-STEM model has increased. Both the lowest, highest and average scores all experienced an increase.

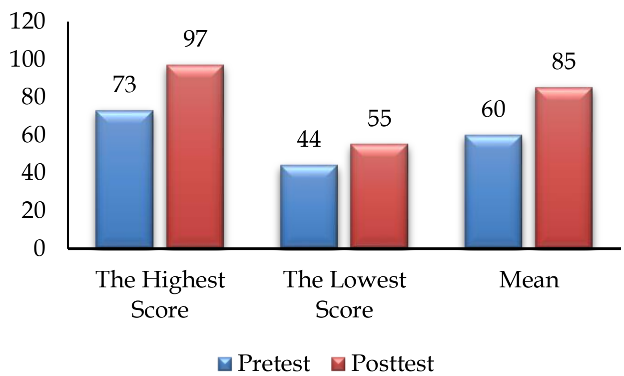


**Figure 6.** Student scientific literacy score

Next, a hypothesis test was carried out to determine the effectiveness of the PjBL-STEM model on student scientific literacy. Before testing the hypothesis, the prerequisite hypothesis test is first carried out, namely the normality test. The results of the normality test can be seen in Table 10. Table x shows a sig value > 0.05, it can be said that the data is normally distributed. After the scientific literacy data is declared normal, it is then continued with hypothesis testing, namely the T-Paired Test. This test was carried out to determine whether there was a significant difference between the pretest and posttest scores. The results of the tests carried out can be seen in Table 11.

**Table 10.** Hypothesis Prerequisite Test Results

| Hypothesis Prerequisite Test | Significance value |
|---|---|
| Normality test | 0.182 |

**Table 11.** T-Paired Test Results

| Hypothesis Test | Significance value |
|---|---|
| T-Paired Test | 0.000 |

Table 11 shows that the 2-tailed sig. value is 0.000 <0.05. Thus, H0 is rejected and Ha is accepted, it can be said that there is a difference in scientific literacy scores before and after being given intervention with the PjBL-STEM model. After carrying out the T-Paired test, the N-Gain analysis was continued to determine the effectiveness of the PjBL-STEM model on scientific literacy scores. The analysis results show the average N-Gain score is 0.5. Based on Table 5, it is known to be in the quite effective category.

This scientific literacy is really needed by basic education students as prospective elementary school educators (Akcanca & Ozsevgec, 2017; Rohman et al., 2021; Taufiq & Rokhman, 2020). Mastery of scientific literacy is essential in developing creativity in solving everyday problems and in careers (Agustina et al., 2023). Integrating STEM in learning can develop students' scientific literacy (AShernoff et al., 2017; Kelley & Knowles, 2016).

The results of this research show that the implementation of PjBL-STEM into learning is able to increase students' scientific literacy. This is in line with Afriana (2022) which states that PjBL-STEM increases scientific literacy and problem solving abilities. PjBL encourages students to gain more skills in deepening the material taught and applying it in everyday life (Miller et al., 2021). The STEM approach is closely related to daily activities involving four disciplines, namely Science, Technology, Engineering and Mathematics. This integration of STEM in learning can be done at all levels of education, from elementary school to university (Erdogan et al., 2016).

The results of this study are also in line with previous research by (Berliana et al., 2024) STEM integrated with PjBl proved to be able to improve science literacy with an effect size of 3.32 in the "high" category. Similar research was conducted by Anggereini et al. (2023) that the innovation of the PjBL STEM model can improve students' literacy as shown by the results of the T test with a sig value. (2-tailed) <0.05 and the correlation test results which show namely the value of sig. (2-tailed) < 0.05.

## Conclusion

The implementation of PjBL-STEM in learning is able to encourage students to understand existing environmental issues. With the project, they are guided and invited to participate in designing problem-solving strategies and resolving existing problems, thereby being able to develop scientific literacy skills. Based on analysis using the t-paired test, information was obtained that H0 was rejected and Ha was accepted, in other words there were differences in students' scientific literacy scores before and after being given the intervention. The analysis was continued with the N-Gain test and the results showed that PjBL-STEM was effective in increasing scientific literacy in the medium category. Based on these findings, it is recommended that educators facilitate the development of students' scientific literacy skills as a provision for solving daily problems and career needs.

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There is no conflict of interest in this research.

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