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Effectiveness of Implementing Problem-based Learning Model in Improving Science Literacy on Environmental Pollution Material in High School

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Abstract: This study aims to determine the effect of the Problem-based Learning (PBL) model on improving the scientific literacy of class X students of SMAN 1 Piyungan on environmental pollution material. The research method used is a quasi-experimental design with a non-equivalent control group design. This research was conducted at SMAN 1 Piyungan, even semester of the 2023/2024 academic year. The sample was class E1 as an experiment and class E2 as a control with the same number of students, namely 36 students. Data on students' scientific literacy abilities were obtained using multiple-choice questions. Analysis of the results of students' scientific literacy abilities was calculated using nonparametric statistics, namely the Mann Withney test. The PBL model is effective in improving students' scientific literacy abilities, as can be seen from the results of students' average scores or the results of the Mann Withney test. The average result of scientific literacy abilities in the experimental class was 77.20 with an N-Ggain value of 0.77, indicating that the increase was in the high category, while the average scientific literacy ability in the control class was 41.28 with an N-Ggain value of 0.41, indicating that the increase was in the moderate category. Based on the Mann Whitney test, the students' scientific literacy ability obtained a sig. (2-tailed) <0.05, meaning that there is a significant difference in students' scientific literacy ability between the control class and the experimental class. Based on the data analysis, it can be concluded that students' scientific literacy ability increases with the PBL model on environmental pollution material.

Keywords: Environmental pollution; Problem-based model learning; Scientific literacy

Introduction

Education in the 21st century is characterized by the development of information technology. Students are required to be able to adapt to technological developments and be able to use them wisely to be able to balance the development of science and technology with various alternative efforts to fulfill life's needs based on knowledge. The 2016 World Economic Forum stated that students need 16 skills to be able to survive in the 21st century, namely basic literacy, competency and character. Scientific literacy is one part of these 16 skills. 21st century skills consist of four main domains, namely literacy, inventive thinking, effective communication and high productivity (Nurdini et al. 2018).

Literacy is the ability to imply scientific knowledge, identify questions and draw conclusions based on scientific evidence. This ability helps students to understand and help make decisions naturally (Ardiyanti et al. 2019). Scientific literacy is defined as an individual's ability to apply their knowledge to identify

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questions, understand, describe scientific explanations, organize and construct new knowledge, draw conclusions based on various scientific evidence, and the ability to develop hypothetical thinking patterns so that they can participate and overcome various ideas and issues related to science. (Pertiwi et al. 2018). It is very important for students to master scientific literacy so that they understand more about the environment and problems that must be solved with science and technology-based knowledge (Rosidi 2021).

The 2018 PISA score results by the OECD show that scientific literacy skills in Indonesia have decreased compared to the 2015 PISA results (Merta et al. 2020). The results of the PISA assessment of Indonesian students for the last four years, namely 2006, 2009, 2012 and 2015, the average achievement of scientific literacy scores is still relatively low in the score range of 382-403 (Hidayah et al., 2019) . In 2018 scientific literacy was still in the low category and experienced a decline with a score of 396 (Kemendikbud, 2019). The results of several previous studies show that the scientific literacy skills of grade X high school students in various cities are still relatively low (Angraini, 2014; Bagasta et al., 2018; Diana et al., 2015; Rahmadani et al., 2022; Rizkita, 2016; Sutrisna, 2021). Based on the latest PISA score results in 2022, Indonesia's scientific literacy skills are still in the low category with a score of 383, experiencing a decrease in score compared to 2018 (OECD 2023).

Students' scientific literacy can be improved by implementing appropriate learning models. Learning that can support the achievement of 21st century competencies is student-centred learning, group collaboration and learning that is directly related to real life problems (Thurrodliyah et al. 2023). The learning model that provides opportunities for students to discover their own knowledge and play an active role in learning is the problem- based model learning (PBL). Umamah et al. (2018) stated that the PBL model will stimulate students to analyze problems, formulate hypotheses, collect data, analyze data and conclude answers to the problems presented.

The PBL learning model is learning that uses real problems, summarizes information, assesses its logic and validity in a context. This model can train, facilitate and improve students' scientific literacy skills through investigation and analysis activities. Learning processes related to real and scientific problems have a positive impact on aspects of scientific literacy competency (Rubini et al. 2019). According to Alatas et al. (2020), Suwono (2015) in his research stated that the PBL learning model had an effect on increasing students' scientific literacy skills. According to Utami et al. (2022) that learning with the PBL model is better used than Discovery learning Learning in teaching biology. Meaningful learning results from problem-based learning activities (Nauli et al., 2022).

The application of the PBL model to scientific literacy requires reviewing basic concepts in order to find a strategic connection to the PBL model. Further review makes it possible to discover the potentials of the PBL model as the right model choice in achieving increased scientific literacy in the future. Based on this view, the author is interested in conducting research regarding the application of the PBL learning model to students' scientific literacy abilities. Journal data discussing the PBL model on the scientific literacy of high school students from 2018 to 2023 is also needed to support this research. The more detailed aim of this article is to find out how the application of the PBL model in learning increases the scientific literacy of high school students. It is hoped that this article can provide insight into future research that will examine the theme of the PBL model and scientific literacy.

Method

The research method used is quasi - experiment research). The research design used is a non- equivalent design controls groups design. This research was conducted in April 2024 at SMAN 1 Piyungan. The population in this study were all students of class X (Phase E) of SMAN 1 Piyungan. The sampling technique uses purposive sampling. The criteria used in selecting the sample are groups that have relatively the same level of ability between the two groups. Classes were drawn randomly, the results of sample selection were class E1 as the experimental class, and E2 as the control class with the same number of students, namely 36 students.

The instrument used in this research is a test instrument (multiple choice questions) consisting of 20 questions. This instrument is used to measure students' scientific literacy abilities, especially in the aspect of scientific literacy competency. The test questions used in the research have been tested for validity by expert lecturers (Validators) through questionnaires with a Likert scale and test questions on students in order to determine the quality of the questions that will be used in the research.

The test instrument that has been validated by the validator is then tested on students who have previously studied environmental pollution material. The resulting data obtained was then analyzed using SPSS 22 software to see the validity and reliability of the questions. The reliability values of the questions are then interpreted by the criteria in the guidelines according to Sugiyono (2014) which can be seen in (Table 1).

Data analysis of students' scientific literacy abilities used SPSS 22 software which began with prerequisite tests in the form of normality, homogeneity and hypothesis tests. The research data obtained is normally distributed and homogeneous, a parametric test (Independent t-test) will be carried out, whereas if the data obtained is not normally distributed and not homogeneous then a non-parametric test (Mann Whitney) will be carried out.

Table 1. Reliability Scores *Conbach Alpha*

Cronbach's value Alpha	Reliability
0.00 ≤ r < 0.20	Very Low
0.20 ≤ r < 0.40	Low
0.40 ≤ r < 0.60	Enough
0.60 ≤ r < 0.80	Tall
0.80 ≤ r < 1.00	Very high

N-Gain test is normality gain obtained from the pre-test and post-test results, the calculation of the average N-Gain value was carried out to see the increase in students' scientific literacy abilities. Calculating the normalized gain score based on the following formula (Hake 1998) can be seen in (Table 2).

$$\text{N-Gain} = \frac{\text{posttest score} - \text{pretest score}}{\text{maksimum score} - \text{pretest score}} \quad (1)$$

Table 2. N-Gain Index Criteria

Score Intervals	Classification
0.00 ≤ gain score ≤ 0.3	Low
0.3 ≤ gain score ≤ 0.7	Enough
0.7 ≤ gain score ≤ 1.0	Tall

Result and Discussion

Literacy abilities were measured using a scientific literacy test question instrument in the form of multiple choices before learning (Pre-test) and after learning (Post-test) environmental pollution material. The data was then analyzed using the SPSS version 22 program, then the descriptive results of the students' scientific literacy ability data were as follows (Table 3).

Table 3. Descriptive Results of Students' Scientific Literacy Ability Data

Information	Control Class		Experimental Class	
	Pre-test	Post-test	Pre-test	Pre-test
Minimum	6	6	6	9
Maximum	13	15	15	16
Mean	8.67	11.44	9.88	13.28

Scientific literacy data is based on the results of normality tests and homogeneity tests. If the scientific literacy data is normally distributed and homogeneous, then the data is analyzed using parametric statistics (Independent t-test). However, if the scientific literacy data obtained is not normally distributed and homogeneous, then the data is analyzed using nonparametric statistics (Mann Whitney-Test). The results of the normality test are presented in (Table 4), while the results of the homogeneity test are presented in (Table 5).

Table 4. Results of Normality Test Data on Students' Scientific Literacy Abilities

		Shapiro-Wilk		
	Class	Statistic	df	Sig.
Scientific Literacy	Control	.906	36	.005
	Experiment	.826	36	.000

Based on the results in (Table 4), it shows that the Sig. in the control class and experimental class are 0.005 and 0.000 < 0.05, so it can be concluded that the data on students' scientific literacy results is not normally distributed.

Table 5. Results of Homogeneity Test Data on Scientific Literacy Abilities

		Levene Statistic	df1	df2	Sig.
Scientific literacy	Based on Mean	22.303	1	70	.000
	Based on Median	19.994	1	70	.000
	Based on Median and with adjusted df	19.994	1	60.816	.000
	Based on trimmed mean	22.331	1	70	.000

Based on the results in (Table 5), it shows that the Sig. on based on the mean is 0.000 < 0.05, so it can be concluded that the data on students' scientific literacy results is not homogeneous. The results of the student scientific literacy data obtained will then be analyzed using nonparametric statistics using the Mann Whitney test. The results of the Mann Whitney test are presented in (Table 6).

Table 6. Mann's Test Withney Students' Scientific Literacy Abilities

	Scientific literacy
Mann-Whitney U	416.000
Wilcoxon W	1082.000
Z	-2.660
Asymp. Sig. (2-tailed)	.008

Based on the results in (Table 6), it shows that the value of Asymp. Sig. (2-tailed) is 0.008 < 0.05, so it can be concluded that there is a difference in students' scientific literacy abilities between the experimental class and the control class. Because there are significant differences, it can be said that there is an influence of using the PBL model in interactive learning media on increasing

students' scientific literacy skills. The magnitude of the increase in students' scientific literacy abilities is presented in (Table 7).

Table 7. N-Gain Score Test Results for Students' Scientific Literacy Abilities

Class	Mean	Effectiveness interpretation criteria	N-Gain score	Division criteria
Control	41.28	Less effective	0.41	Currently
Experiment	77.20	Effective	0.77	Tall

Based on the results in (Table 7), it shows that the scientific literacy ability of control class students increased by 0.41 with medium criteria, while in the experimental class it was 0.77 with high criteria. This shows that the use of the PBL model in learning is more effective in improving students' scientific literacy abilities than the use of the 5M synthetic approach. The increase in scientific literacy abilities of control class students compared to the experimental class is presented in the following graph (Figure 1).

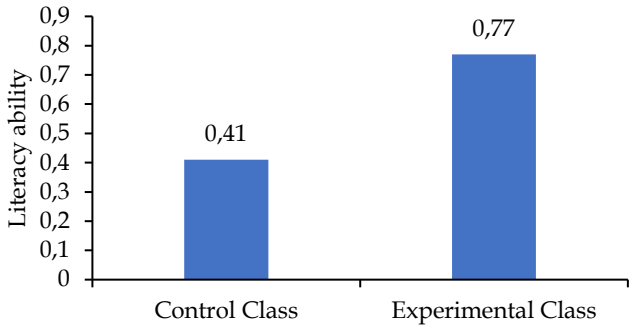

Figure 1. Graph of increasing students' scientific literacy abilities

Literacy abilities of students in the experimental class experienced a higher increase compared to the control class. Using the PBL model in learning is more effective in improving students' scientific literacy skills than using the 5M synthetic approach. The increase in each aspect of scientific literacy competency before and after learning with the PBL model in the experimental class is presented in the following graph (Figure 2).

Literacy competency aspect experienced a significant increase in the experimental class. Based on the graph in (Figure 2), it shows that there has been an increase in all aspects of scientific literacy competency in the experimental class. The value of the increase in the scientific literacy competency aspect before and after learning with the PBL model, namely in the aspect of explaining scientific phenomena, increased by 37%, in the aspect of designing and evaluating scientific investigations by 24.6% and in the aspect of interpreting scientific data and evidence by 34.5%. Therefore, it can be concluded that the use of the PBL model in learning activities can improve every aspect of scientific literacy competency.

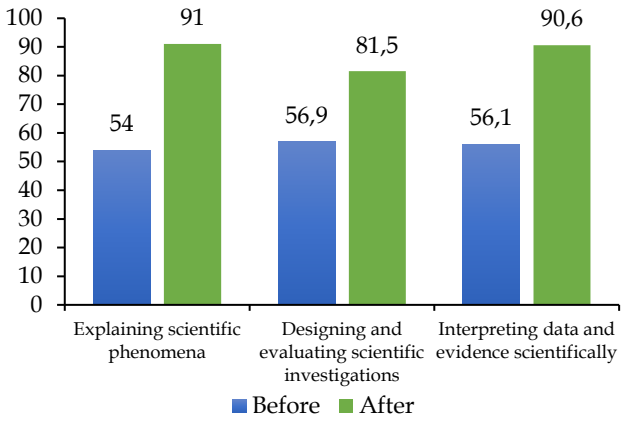

Figure 2. Graph of improvement in scientific literacy competency aspects before and after product use

This discussion is based on research data obtained from two classes, namely class E1 as an experiment and class E2 as a control class. Learning using the PBL model is implemented in the experimental class, while in the control class the 5M scientific approach is implemented in learning activities. The learning process was carried out during 2 meetings for each class on environmental pollution material. On the first day, at the beginning of the meeting in the learning process, students were given pre-test questions in the form of multiple choice questions and on the second day, at the end of the meeting in the learning process, students were given post-test questions in the form of multiple choice questions. This question is used to obtain data to measure students' scientific literacy abilities. Nuzula et al. (2022) stated that increasing aspects of scientific literacy cannot be separated from learning activities that are directly related to the environment.

The graph in (Figure 1), the average N-Gain score was 0.41 in the medium category for the control class and 0.77 in the high category for the experimental class. The increase in scientific literacy skills of experimental class students was greater than that of the control class. Based on this, it shows that the use of the PBL model in learning is more effective in improving students' scientific literacy skills. In accordance with the research results of Widiana et al. (2020), Alatas et al. (2020), that the PBL model is a learning model that can improve students' mastery of material and the formation of students' scientific literacy abilities, especially in the competency aspect. Agree with Utami et al. (2022),

Nurtanto et al. (2020) stated that the application of problem-focused learning shows good abilities to solve problems, so that the PBL model has a positive impact on increasing scientific literacy abilities.

The aspect of explaining scientific phenomena experienced the highest increase in the experimental class, with an average of 91% in the very high category. Application of the PBL model in learning in experimental classes by presenting environmental pollution problems in everyday life, causes, impacts and solutions. The PBL learning activities presented emphasize problems to grow students' abilities in solving problems in real situations. Students have the ability to build their own knowledge through learning activities. Learning will focus on the problems presented, so that students do not need to study unrelated material to reduce students' burden in learning. Agree with Widiana et al. (2020) that the application of the PBL model can stimulate students to be active and critical in finding or creating solutions to problems. Students actively convey ideas, thoughts and solutions in the problem solving process. This process will strengthen the aspect of explaining scientific phenomena in scientific literacy competencies. Nurhayati et al. (2023) stated that at this stage students have the opportunity to evaluate the entire learning process so that students understand the meaning of the problem and solve it correctly.

The aspect of designing and evaluating scientific investigations experienced the lowest increase in the experimental class, with an average of 81.5% in the very high category. Application of the PBL model in learning in experimental classes by guiding students in investigations to search for and analyze scientific evidence. Teachers can present a problem as a whole that is contextual and scientific in nature. Teachers also guide students in the process of searching for and collecting scientific references to find solutions to the problems presented. Describe real phenomena in the material studied, so that students can relate the material studied to phenomena in everyday life. Agree with Fauziah et al. (2019) that the systematic stages of the PBL model can develop problem-solving abilities through investigation and analysis activities of everyday phenomena.

The PBL learning model is a student-centered learning model. A learning process like this will give students the opportunity and facilitation to build their own knowledge. In agreement with Qomariyah et al. (2019) PBL is a student-centered model for developing learning abilities and engagement. Learning activities will run flexibly according to students' needs and learning styles so that teachers do not play a central role in learning activities but as facilitators. Students will gain a deep understanding so that they can improve the quality of students. The problems presented will stimulate students to carry out further scientific investigations. Agree with Permatasari et al. (2019) that involving scientific investigation activities in learning activities can help students to actively build their own knowledge.

Students will be encouraged to learn how to design and design scientific investigations to answer assumptions and questions that originate from students and questions in learning activities. In accordance with the statement of Widiana et al. (2020) that the PBL learning model focuses students on problems and questions so that students are able to solve problems using scientific concepts and principles. Agree with Utami et al. (2022) that this is in line with scientific literacy skills which direct students to carry out scientific investigations in solving problems. According to Widiana et al. (2020) that the application of the PBL model can improve aspects of designing and evaluating scientific investigations on scientific literacy competencies. Students learn how to formulate problems presented by the teacher and implement them in the real world. This process trains students to think critically, communicate and evaluate.

The aspect of interpreting data and evidence scientifically also increased in the experimental class, with an average of 90.6% in the very high category. Application of the PBL model in learning in experimental classes by training students to develop and present the results of investigations such as reports in PowerPoint format, which will then be presented to communicate and conclude learning. Students individually or in groups are directed to search for and analyze information from phenomena and problems provided by the teacher. Student involvement in the discovery process can increase knowledge and hone their skills. Students are also formed to have a sense of responsibility to find solutions to solve problems. Agree with (Juriah & Zulfiani, 2019) that the PBL model provides space for students to exchange ideas and concepts in solving problems. Widiana et al. (2020) and Alatas et al. (2020) stated that applying the PBL model in learning can improve aspects of interpreting data and evidence scientifically. Solutions from the results of formulating problems can develop scientific evidence from relevant and scientific sources to create solutions. Students will communicate opinions with the support of scientific references that have been analyzed.

Scientific investigations will encourage students to find various information such as data and scientific evidence related to the problems presented. This activity will hone students' abilities to search, read, analyze, conclude and communicate based on the information obtained. The findings obtained by students will be the

basis for making appropriate decisions and solutions in solving environmental problems around them. In accordance with the statement of Yusuf et al. (2023) that the PBL model syntax is able to make students active and facilitate students' independent learning and solving problems. Nurhayati et al. (2023) added in their research that the application of the PBL model provides an innovative approach to increasing students' scientific literacy. PBL creates an engaging and relevant learning environment, by integrating elements of technology, activities and mind mapping. Students gain a better understanding of scientific concepts, as well as foster curiosity about the problems presented in the learning material to increase students' overall scientific literacy.

Based on the description of the discussion regarding the application of the PBL model in learning, this shows that the use of the PBL model in learning is effective in improving students' scientific literacy skills. The application of the PBL model to the experimental class showed better literacy skills than the control class. The PBL model can significantly improve students' problem solving abilities so that students' academic achievements can also increase. Learning activities direct students to be active in learning. The description of the stages in the PBL model also facilitates aspects of scientific literacy competency, so that this can influence students' level of scientific literacy skills.

Conclusion

The PBL model applied in learning in the experimental class is more effective in improving students' scientific literacy abilities, compared to the 5M scientific approach which is less effective in improving students' scientific literacy abilities. The syntactic description of the PBL model can facilitate and build aspects of scientific literacy, this can be seen from the increase in all aspects of students' scientific literacy competencies. The average increase in aspects of scientific literacy competency before and after using the PBL model in learning, namely the aspect of explaining scientific phenomena, increased by 37%, the aspect of designing and evaluating scientific investigations by 24.6% and the aspect of interpreting scientific data and evidence by 34.5%. The PBL model is effectively used to improve the scientific literacy skills of class X high school students on environmental pollution material. The application of the PBL model is only limited to environmental pollution material to increase scientific literacy, so further research is needed for other skills. There is still a possibility that if applied to other materials it will have different results.

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Author Contributions

Conceptualization, S. and Y.P.R.; methodology, S.; validation, A.K.S.; formal analysis, Y.P.R.; investigation, Y.P.R.; resources, S. and Y.P.R.; data curation, Y.P.R.; writing—original draft preparation, S. And Y.P.R.; writing—review and editing, S. And Y.P.R. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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