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Effectiveness of the problem-based learning model to improve mathematical literacy of junior high school students

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Abstract

Existing studies show that learning using problem-based learning teaching modules can significantly improve mathematical literacy in class VII students at SMPN 1 Kampar. A quasi-experimental design was used, with the research population consisting of VII-grade students of SMPN 01 Kampar. The research sample consisted of two classes: VII-B, the control class, and VII-A, the experimental class. The data analysis technique employed was a posttest analysis of the results from the mathematical literacy test, using the t-test to determine whether there was an increase in performance, as indicated by N-Gain data. The results of data analysis showed that the *Independent Sample t-test* obtained a significance value of 0.001, which means that there is a significant difference between the control class and the experimental class. The average value of *N-Gain* was 0.6722 for the experimental class, categorized as medium, and 0.2970 for the control class, also categorized as medium. Indicates that learning using the PBL model increases mathematical literacy higher than classes that do not use the PBL model. These findings reveal that there is an increase in mathematical literacy, thus indicating that the use of the PBL model helps improve mathematical literacy.

Keywords: effectiveness, problem-based learning model, math literacy

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I. Introduction

Mathematical literacy is one of the essential skills that students need to have in the modern era to solve various problems in everyday life. This aligns with the OECD's (2019) statement, which emphasizes that mathematical literacy is essential for every individual, enabling them to understand the application of mathematics in everyday life and make informed, logical decisions when solving problems. Purnomo, Hidayat, & Mulyani (2022) also concluded that possessing mathematical literacy enables individuals to apply various procedures, utilize their knowledge and competencies, and demonstrate confidence in using this knowledge in everyday life.

According to the results of the 2022 PISA survey, the level of mathematical literacy among Indonesian students remains relatively low, with a score of 366; this score is significantly below the

average score of OECD countries, which stands at 489 (OECD, 2023). The content tested in PISA aligns with the mathematics materials in the secondary school mathematics content standards, illustrating that students have not been able to apply the material they have learned to solve mathematical literacy problems. The low mathematical literacy of students is caused by their unfamiliarity with questions that require logical and analytical thinking in everyday life contexts (Dinni, 2018). This is also described by Nuurjannah, Amaliyah, & Fitrianna (2018) that students are less able to practice facts and data from many sources when problem solving.

One of the causes of low mathematical literacy is due to learning models that do not provide space for students to think critically, explore real problems, and connect mathematical concepts with everyday life**.** Teacher-centered learning tends to emphasize mastery of formulas and mechanistic procedures. Efforts in creating good learning can be done by preparing learning that is able to develop students' mathematical literacy. Learning activities are supported by using the PBL model. PBL is a learning model that presents real problems in everyday life as a context for students to learn about mathematical skills owned by students (Khotimah & Aini, 2022). PBL is also considered a learning model that can activate students, to encourage students to develop their own knowledge and skills in solving problems that are oriented to everyday life (Fitri, Yuanita, & Maimunah, 2020)

The connection between PBL and mathematical literacy lies in the fact that PBL presents real-world problems encountered in everyday life, which challenge students to explore information based on their existing knowledge (Arifin, 2023). Then, by using the PBL model, students become more active and can apply all their abilities in solving mathematical problems (Pratiwi Ilma, Putri, & Hiltrimartin, 2024). Meanwhile, mathematical literacy is also necessary so that students can formulate, apply, and interpret mathematics in various contexts. This includes using mathematical concepts, facts, procedures and tools to describe, explain and illustrate an existing phenomenon.

The material that is the focus of the research is a statistical presentation of data, where a statistical presentation of data requires mathematical literacy that is relevant to everyday experiences and situations. However, students still experience challenges in dealing with problems related to data presentation statistics, this is because students still have difficulty in communicating information on problems, mathematization, difficulty in determining problem solving strategies, and reasoning and difficulty providing argumentation on problems, so that they are wrong in concluding problem solving (Prasasti & Sumardi, 2022)

Previous research has shown that the Problem-Based Learning (PBL) model has been proven effective in improving students' active engagement and problem-solving abilities in general. However, previous research has not focused much on the application of PBL to improve mathematical literacy skills in statistical data presentation. Therefore, this study offers a novel approach by integrating the PBL model into statistical data presentation materials and specifically analyzing students' difficulties within the context of mathematical literacy. This is expected to provide an empirical contribution to the development of more effective and contextual problem-based mathematics learning.

Based on this background, the researcher aims to investigate the effectiveness of the PBL model in enhancing students' mathematical literacy in understanding statistics. This research seeks to determine whether students' mathematical literacy skills improve significantly after using the PBL model compared to before.

II. Research Method

This research is quasi-experimental (Quasi Experiment), using a pretest and posttest design. The population used was class VII students of SMPN 01 Kampar in the 2024/2025 school year. The research sampling was carried out using a purposive sampling technique because the research subjects were chosen deliberately

based on certain considerations that were in accordance with the research objectives, and the selection of this technique was carried out so that researchers could obtain data that was more relevant, in-depth, and in accordance with the research focus. Therefore, class VII-B was selected as the control class, and class VII-A as the experimental class, with 30 students in each class.

The data collection instrument in this study consisted of a description question, totaling 3 items, on both the pretest and posttest. The question instrument used has been declared to meet the criteria of validity, reliability, difficulty level, and differentiating power of the questions that have been determined. The questionnaire instrument was declared valid after being tested for validity using the antae is application, with the test results of R count on each question item greater than R table 0.376. Therefore, each question item was deemed valid and could be used in the research. The reliability test of the question instrument has a correlation coefficient of 0.8883 with a very high category.

Their questions in the study can be used after passing their level of difficulty test. Based on their test results of the level of difficulty in question number 1, with a level of difficulty of 0.42, it is categorized as having moderate difficulty; in question number 2, with a level of difficulty of 0.43, it is categorized as having moderate; in question number 3, with a level of difficulty of 0.35 categorized as having moderate. Their analysis of the difficulty of the question items revealed that the questions can be used to collect data in their study, as all question items are categorized as moderate. After testing the level of difficulty of their question, the test is carried out with a differentiation test, using the results of the differentiation index for question numbers 1 to 3 in the interval 0.20-0.39. Specifically, number 1 is 0.31, number 2 is 0.39, and number 3 is 0.38. Based on the results of the differentiation analysis conducted, the questions already exhibit good differentiation, indicating that they can distinguish between students who have mastered the material and those who have not. Thus, the test questions can be used to collect data.

Data collection steps are carried out by giving the same pretest questions to students to determine their initial ability. Furthermore, the control class received training using learning models without PBL, which employed conventional learning models where the teacher played a more dominant role as the primary source of information. In contrast, the experimental class received training using PBL learning models. Each class carried out 4 learning meetings. After students are given training, both classes are given a posttest to see their effect or increase in mathematical literacy from the PBL learning model applied during learning.

After the pretest and posttest were conducted in both classes, the data obtained were then subjected to two prerequisite tests: the normality test and the homogeneity test, using SPSS 25 software. The data from the posttest scores, processed by the normality test, showed a significance level of 0.149 for the control class and 0.155 for the experimental class, with results indicating a value greater than 0.05. Therefore, the data are distributed following a normal curve. The homogeneity test of the posttest values of the control class and the experimental class yielded a significance level of 0.789, which is greater than 0.05. Therefore, the samples in this study are homogeneous, indicating that the research data groups have the same variance. After the data is known to be normally distributed and the data comes from a homogeneous sample, the following hypothesis test is the t-test to assess the effect or improvement of the PBL model learning using mathematical literacy, with learning without PBL using mathematical literacy. Their data analysis process uses the help of Microsoft Excel 2010 and SPSS 25 software.

III. Results and Discussion

The PBL learning model, which incorporates mathematical literacy, provides students with new experiences in learning mathematics that expose them to real-world daily

problems during the learning process. The learning process in class was attended by students from Class VII-A and Class VII-B, with each class comprising 30 students. During the learning process, students can independently understand the learning objectives of the material's indicators, define and organize problems, solve problems, and provide conclusions related to problems in mathematics learning.

In the control class, students showed low curiosity about the problem during their learning process. In contrast, in their experimental class, students were more active, had higher curiosity, and were able to solve problems independently. Their cultivation of mathematical literacy is achieved by providing students with directions to read, define, analyze, and solve problems. Their learning process using the PBL model was reviewed in terms of their ability to solve problems and draw conclusions. Data from this study were obtained from the number of posttest answer scores completed by students. To determine whether the posttest data in the control and experimental classes are normally distributed and homogeneous, a preliminary test is conducted. Their normality test uses the Kolmogorov-Smirnov formula with SPSS 25 software. Their normality test is shown in Table 1.

Table 1. Normality test results of mathematical literacy posttest values

Class	Kolmogorov-Smirnov[a]		
	Statistic	Df	Sig.
Experiment Class	0.149	29	0.086
Control Class	0.155	29	0.172

Based on their results of the normality test using SPSS 25 software in Table 1, it can be seen that the sample has been normally distributed, as evidenced by the results of the normality test in the control class, obtaining a significance of 0.172, and in the experimental class of 0.086, where the value is greater than 0.05. It can be concluded that the data has been distributed following a normal curve. After their data is declared normally distributed, their homogeneity test is carried out to test whether their sample is from a homogeneous population or not. The homogeneity of this study is based on the number of posttest answer scores obtained by students. They homogeneity tested the data using Levene's Statistic formula with SPSS 25 software in Table 2 below:

Table 2. Homogeneity test results of mathematical literacy *posttest* values

Levene Statistic	df1	df2	Sig.	Conclusion
0.018	1	58	0.892	Homogeneous

Based on their results of the homogeneity test contained in Table 2, it can be seen that the significance value of the homogeneity test results is 0.892, where the value is more than 0.05, so it can be concluded that the sample in the study is homogeneous or the research data groups have the same variance.

After their prerequisites are met based on the students' posttest results and answer scores, which indicate what they have done, the calculation of the test on the independent sample is continued. Their independent sample t-test in this study was conducted to analyze whether there was a significant difference between the control class and the experimental class using the PBL learning model. Their data used in the independent sample t-test are the posttest values in the control and experimental classes independent sample t-t is in Table 3 below:

Table 3. Independent sample t-test of mathematical literacy posttest score

Class	Average	Standard Deviation	Sig. (2-Tailed)
Experiment	9.50	1.886	0.001
Control	7.40	1.943	

The results of their paired sample t-test, conducted using SPSS 25 software, are presented in Table 3. As shown, the calculated t-value is less than 0.05, indicating that the use of problem-based learning models incorporating mathematical literacy has a significant effect on

student learning outcomes. Based on the results of hypothesis testing data analysis, the experimental class, which was taught using the PBL model with a focus on mathematical literacy, demonstrated higher mathematical literacy skills than the control class, which was taught using conventional learning models.

Furthermore, the average n-gain value is caried out which aims to assess how effective the PBL model is in increasing the average mathematical literacy test scores of students from before and after being applied to statistics material. Their results of their N-gain data analysis are in Table 4:

Table 4. Math literacy n-gain results

No.	Statistical Measures	Improving Students' Mathematical Literacy	
		Experiment Class	Control Class
1.	Average	0.6722	0.2970
2.	Minimum Score	0.17	0.00
3.	Maximum Score	1.00	0.73
4.	Reach	0.83	0.73
5.	Variance	0.056	0.049
6.	Standard Deviation	0.23710	0.22156

The results of Table 4 show that the average N-Gain of Mathematics Literacy in the experimental class is 0.6722, categorized as "moderate," while the control class has an average N-Gain of 0.2970, categorized as "low." This indicates that students who utilize teaching modules based on problem-based learning exhibit a higher increase in mathematical literacy compared to those who do not use these modules. Based on the criteria proposed by Lestari & Yudhanegara (2017), the average posttest score of the experimental class is higher than that of the control class. The increase in mathematical literacy of experimental class students is higher than that of the control class. The teaching module based on problem-based learning is proving effective.

This is also supported by research conducted by Tyaningsih, Septiaji, Utama, & Fitriana (2023), Samad & Nur (2023) and Noor, Purwosetiyono, & Wardani (2024) that there is an increase in students' mathematical literacy by using their PBL model, this is due to the steps of their PBL model, which support each indicator of mathematical literacy. The application of this model can help students understand analysis results, make predictions, and make accurate decisions, as well as improve their analytical skills and understanding of mathematical concepts in relevant contexts (Sutrimo, Sajdah, Veronica, & Sinambela, 2024; Andini, Fuady, & Nursit, 2023).

Many studies have shown that students' mathematical literacy can be improved through learning that applies the right model, as demonstrated by research Sitompul, Lutfi, & Rosidah (2023) and Erria et al. (2023) which indicate that the PBL model has a positive impact on improving mathematical literacy. This statement is reinforced by research conducted by Suciawati, Anggiana, Hermawan, Majalengka, & Pasundan (2023) which demonstrates that the application of the PBL model yields a significant increase in students' mathematical literacy skills compared to the use of conventional learning models.

Devina, Susanto, & Kartini (2021) also revealed that their PBL learning model can accommodate students' higher-level thinking skills, making it easier to reinforce, increase understanding, and enhance knowledge relevant to the world of practice, encourage critical thinking, build leadership skills, cooperation, and learning skills, and motivate learning. The PBL model provides various advantages in the learning process of students, especially in getting used to facing problems; thus, in their future, students can independently determine their direction and actions (Sari, Yandari, & Fakhrudin, 2017).

In line with research Firdaus, Asikin, Waluya, & Zaenuri (2021); Fitriani &

Seityaningsih (2024) PBL model contributes positively to the improvement of students' mathematical literacy due to several reasons, namely, first PBL model presents contextual problems that can motivate students to learn, second PBL encourages active involvement of students in the learning process, third this model motivates the use of various strategies, fourth PBL provides space to develop the potential of students, fifth builds a collaborative learning atmosphere, sixth PBL helps create a quality learning process. Overall, the application of the PBL model is proving effective in improving students' mathematical literacy in solving real-world problems across various contexts, thereby strengthening their ability to understand and apply mathematical concepts meaningfully.

Based on the results of data analysis, the experimental class achieved higher results than the control class in mathematical literacy skills. This is influenced by their use of learning models, including PBL models, which focus on students (student cohort) and train them to solve real-life problems by emphasizing communication, cooperation, formulating ideas, and developing their reasoning skills. Handoko (2019) explains that the PBL learning model can affect students' curiosity, thereby training and influencing their mathematical literacy skills. This is because the PBL model involves students participating in learning activities and solving real-world problems. Students' mathematical literacy skills, as applied through the PBL model, involve students in their learning process (student-centered) so that they can express their own concepts in solving, formulating, and interpreting the problems they face. Additionally, collaborative learning facilitates a deeper understanding of the material for students.

This active involvement is the basis for improving mathematical literacy skills, because students not only receive information from teachers, but also construct their own knowledge through a process of inquiry and reflection. Theoretically, improving mathematical literacy through PBL can be explained because this model provides students with the opportunity to directly experience the process of mathematization, namely formulating problems from real contexts into mathematical forms, carrying out solutions, and interpreting the results back into the context of everyday life. In line with research conducted by Astuti, (2018) and Ernia & Mahmudah (2023), which states that there is a positive influence of the PBL model on improving mathematical literacy in junior high school students, the more students are given mathematical problems, the more it will provide students with a stimulus to learn and explore information, thereby improving students' mathematical literacy.

In addition, the results of the data analysis show that the experimental class demonstrated an improvement in mathematical literacy skills, outperforming the control class. This occurs because of the learning approach using the PBL model, which has stages or syntax that can train students to improve their mathematical literacy skills, compared to the control class that employs conventional learning models. According to Madyaratri, Wardono, & Praseityo (2019), learning with PBL models exposes students to problems that aim to train and facilitate their ability to solve problems by using their mathematical knowledge, thereby improving students' Mathematical Literacy skills. The PBL model enables learning through the process of reasoning, prompting students to identify problems through observation and experimentation, and gather information to find problem-solving strategies that enhance students' mathematical literacy (Hayati, Pratiwi, Hasan, & Pujiastuti, 2024).

Habituation to learning with the PBL model needs to be done, so that students can get used to understanding problems with mathematical literacy in the PBL model learning, which is considered difficult for students to do, because they are not used to problems that are not complicated, so that students become less optimal in solving problems with mathematical literacy. According to Pamungkas & Franita (2019), explains that the use of the PBL model learning

can increase students' mathematical literacy can increase, this happens because the stages or syntax in the PBL model include problem identification, independent learning, investigation, exchanging knowledge and assessment, which will facilitate students in improving their mathematical literacy skills so that a generation that is ready for their challenges in the future will be realized.

This research has several practical implications for mathematics learning in schools. First, teachers need to integrate the PBL model more frequently into mathematics lessons, especially for materials related to real-life contexts such as statistical data presentation. Second, learning through PBL can be an effective strategy for developing students' mathematical literacy, a crucial competency for the 21st century. Third, the implementation of PBL can encourage the development of independent, reflective students who are ready to face future challenges, because they are accustomed to thinking critically and systematically in solving problems. However, this research has several limitations. First, their relatively short research period means that students were not yet fully accustomed to the syntax of PBL, resulting in some students still having difficulty understanding complex problems. Second, the limited sample size and the research context, which was conducted only in one school, limit the generalizability of the results. Third, the mathematical literacy assessment instrument may not have fully covered all aspects of literacy (formulation, application, and interpretation) in depth. The researchers suggest that for further research, they implement their PBL model over a more extended period, allowing students to adapt to the problem-based learning approach. Additionally, involving more schools or different levels of education would help obtain more generalizable results. In addition to reading more comprehensive mathematical literacy assessment instruments, it is also integrated with other 21st-century skills, such as collaboration and creativity.

IV. Conclusion

Based on the results of their research, the application of the Problem-Based Learning (PBL) learning model is efficacious in improving the mathematical literacy skills of seventh-grade junior high school students on statistics material. This is evidenced by the results of statistical tests, which show significant differences between the experimental class and the control class, as well as the N-gain value, which falls into the medium category. The PBL model helps students formulate problems, apply mathematical reasoning, and interpret concepts in real-life contexts**,** thereby supporting the overall improvement of their mathematical literacy. Suggestions for future research to develop this research on other mathematical materials or different levels of education, as well as to integrate more complete mathematical literacy indicators to get a more comprehensive picture of the effectiveness of the PBL model.

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