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The Effect of Problem-Based Learning Model on Students Scientific Reasoning and Scientific Attitude Abilities

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Abstract: Scientific Reasoning and Scientific Attitude are important aspects of scientific literacy for students to master because they are directly related to the development of science and technology. This study aims to analyze the effect of the Problem-Based Learning model on students' Scientific Reasoning and Scientific Attitude abilities. This type of research is classified as a quasi-experiment with a non-equivalent control group design. The study population consisted of 13 classes of the 10th grade of MAN 2 Mataram, from which two classes were selected as samples determined by purposive sampling techniques. Data were obtained by administering the Scientific Reasoning test and the Scientific Attitude questionnaire. Data analysis techniques include a comparison of average scores and the Mann-Whitney statistical test. The results showed that the experimental class obtained an average score of 75 points (formal), and the control class obtained a score of 72 points (transitional) on the Scientific Reasoning aspect. On the Scientific Attitude aspect, the experimental class obtained a score of 69 (High) and the control class obtained a score of 63 (Moderate). In addition, the Asympt. sig (2-tailed) value on the Scientific Reasoning aspect is greater than 0.05, which is 0.466, while on the Scientific Attitude aspect it is 0.003 or less than 0.05. Based on these findings, it can be concluded that although the Problem-Based Learning model has a significant effect on Students' Scientific Attitude Ability, its impact on Scientific Reasoning Ability is not statistically significant in the context of this study. This can be influenced by external factors that cannot be fully controlled in the research implementation process.

Keywords: Problem-Based Learning; Scientific Reasoning; Scientific Attitude.

Introduction

21st-century skills are very important skills for students to master in Science Education [1]. Science learning must be integrated with science literacy, which refers to science-based knowledge and technology that is in line with the development of education in the 4.0 era [2]. Science literacy is a strategic way to help students become smart and help them become good citizens. Science education is very important in developing students' science literacy through the teaching and learning process [3].

The 2022 PISA survey revealed that Indonesian students' abilities in science literacy are still in the low category. PISA (Program for International Student Assessment) is a triennial survey of 15-year-old students worldwide to assess the extent to which they have acquired the knowledge and skills needed to participate in social and economic life. The PISA survey focuses on mathematics, reading, science, and creative thinking skills as minor assessment areas. The average score of Indonesian students in science is 383 points, far below the OECD average of 485 points [4].

The assessment framework and analysis of PISA 2022 define scientific literacy as the ability to engage with science-related issues and scientific ideas as a reflective citizen [5]. Scientific literacy can be defined as the ability to use scientific knowledge, identify questions, and draw evidence-based conclusions in order to understand and make decisions about the natural world and the changes that occur within it. This ability is essential for students to understand, identify, explain, and utilize scientific findings to solve problems faced by modern society [6-7]. Scientific Reasoning (SR) and Scientific Attitude (SA) as learning outcomes are included in the aspect of scientific literacy.

Science education, as one of the scientific learning approaches, is related to the way of systematically finding out about natural phenomena. Science learning is not just about mastering a collection of knowledge in the form of facts, concepts, or principles, but also about a process of discovery [8]. As a form of discovery process, effective learning activities are needed to help students develop their thinking skills without neglecting their understanding abilities according to their developmental stage [9]. A learning model that suits the material and student conditions is an effort that can be made to improve the quality of learning [10].

Problem-Based Learning (PBL) exposes students to a problem to find a solution. With this type of learning, students will be trained to use their thinking skills, thereby fostering initiative in increasing knowledge, skills, and meaningful learning outcomes [11]. The application of PBL can also increase students' enthusiasm in discussing, being diligent, and enthusiastic in expressing opinions according to their understanding [12]. This learning model can provide students with extensive experience to develop innovation and learning skills [13]. Attitudes of responsibility, cooperation, discussion skills, and problem-solving abilities are some of the important aspects that can be honed through this learning model [14].

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Problem-based learning aims to prepare students to think critically and analytically, as well as to seek and use appropriate learning resources [15]. Referring to Arends [16], the stage of problem-based learning begins with directing students to a problem. At the beginning of problem-based learning, like all types of lessons, the teacher must clearly communicate the learning objectives, form a positive attitude towards the lesson, and explain what is expected of students. This learning model is oriented towards the learning process experienced directly by students. This type of learning that focuses on the process is referred to as a student-centered learning model [17]. This approach provides opportunities for students to manage learning independently and encourages activeness during the process. This concept can create a learning environment that emphasizes creativity, collaboration, initiative, and independence [18].

Some researchers explain scientific reasoning as thinking about and with scientific knowledge. This definition can be expanded to include sub-skills related to scientific reasoning (i.e., hypothetical-deductive reasoning, controlling variables, hypothesis generation, and evidence-based conclusion drawing) [19]. Lawson and Kuhn further define reasoning as a process that occurs both formally in academic domains and informally in everyday situations as a response to phenomena, events, and natural processes [20].

A scientific attitude is one of the most important outcomes of modern science education. Although some people view a scientific attitude as a product of science education, most people consider it equivalent to the scientific aspect. Science must be taught directly and systematically because science has many characteristics that promote a scientific attitude that distinguishes it from other types of attitudes [21]. Scientific reasoning and scientific attitude help students build scientific literacy, which in turn will enable students to participate in modern life. Scientific Reasoning supports Scientific Literacy by providing the thinking skills necessary to understand and evaluate scientific information effectively. A Scientific Attitude will help students engage actively and positively in science, which strengthens motivation to achieve Scientific Literacy.

Students' abilities in science can be empowered through the application of learning models that facilitate independent learning. A teaching model that helps students understand the structure or main ideas of a discipline is called discovery learning. When discovery learning is applied in science, the learning emphasizes inductive reasoning and inquiry processes that are characteristic of scientific methods and problem-solving [16].

MAN 2 Mataram, as one of the State Madrasah Aliyah in West Nusa Tenggara, is a suitable location for research to measure students' scientific literacy. The results of observations show that this madrasah has a relatively high number of students with diverse backgrounds. These characteristics are very suitable for representing the level of students' scientific abilities in West Nusa Tenggara. Furthermore, it was found that the learning model in Biology, as part of science learning applied in this madrasah, tends to be teacher-centered. The application of teacher-centered science learning models can be a factor in the lack of student focus in the learning process. This can directly affect the level of students' scientific abilities. Innovative learning is needed in the form of applying student-centered learning models. One learning model that is widely adopted to support student-centered learning is the Problem-Based Learning model [22].

Problem based learning models can facilitate students in developing Scientific Reasoning and Scientific Attitude abilities. This effort is made through problem exploration activities in the surrounding environment to improve scientific literacy. Research conducted by Mazlin [23] reveals that the application of the PBL model has a significant influence on student learning outcomes. The research shows an increase in student learning outcomes in general. However, Scientific Reasoning and Scientific Attitude of students as part of science learning outcomes have not received special attention in that research, making research on "The Effect of Problem-Based Learning Model on Students Scientific Reasoning and Scientific Attitude Abilities" important to conduct.

Research Methods

This study uses a quantitative approach that focuses on measuring variables through tests and questionnaires. The type of research used is a quasi-experiment. Sugiyono [24] refers to this type of research as a development of true experimental research that cannot fully control external variables. The research design is a non-equivalent control group with one control class and one experimental class. The experimental class is treated with the Problem-Based Learning model, while the control class is treated with a conventional learning model. This research was conducted over two meetings in the even semester of the 2025/2026 academic year.

The research was conducted at MAN 2 Mataram, located at Jl. Pendidikan No.25, Dasan Agung Baru, Selaparang District, Mataram City, West Nusa Tenggara, with a postal code of 83125. The population of this study consisted of all students in class X. The sample was determined using a purposive sampling technique. Students in class X.2 were selected as the experimental class, and students in class X.3 as the control class.

The instrument used to obtain data on students' Scientific Reasoning abilities was a multiple-choice test consisting of 10 pairs of items, adjusted to three indicators of Scientific Reasoning according to Lawson [25], namely correlational reasoning, control variables, and hypothesis-deductive reasoning. The instrument had previously been evaluated by experts and tested to determine its validity and reliability. The instrument used to obtain data on students' Scientific Attitude abilities was a non-test questionnaire with a Likert scale, compiled based on indicators of Scientific Attitude according to Harlen and Jelly [26] developed by Anwar [27].

Data analysis was conducted using mean value comparison to measure the difference in the level of Scientific Reasoning and Scientific Attitude abilities of students. Additionally, hypothesis testing was conducted using the Mann-Whitney test. Prerequisite tests, such as normality test, were used to determine whether a set of data comes from a normally distributed population or not [28], while homogeneity test was intended to show that the data comes from a population with the same variance [29]. These tests were conducted using SPSS statistical software.

Results and Discussion

Average value of Scientific Reasoning

The assessment of students' Scientific Reasoning abilities was conducted through the administration of a test instrument consisting of 3 pairs of questions to assess correlational reasoning and hypothesis-deductive reasoning, and 4 pairs of questions to assess control variable reasoning. The test results were then categorized into three stages of reasoning with a range of 0-100, namely the concrete operational, transitional operational, and formal operational stages. Based on the analysis results, it was found that the average pre-test score obtained by the experimental class was 65 points, while the control class was 61 points. These scores indicate that both sample groups were in the transitional reasoning category. The transitional reasoning stage is a stage when a child's thought pattern is between the concrete operational and formal operational stages, where the child can already demonstrate the ability to think abstractly but only in certain contexts [30].

The average post-test score in the experimental class showed a value of 75 points, which falls into the formal reasoning category, while the score in the control class was 72 points, which falls into the transitional reasoning category. Formal reasoning refers to an individual's ability to use reason accurately according to their developmental stage. Marinda [31] states that at this stage, a person can already write and develop deductive hypotheses about ways to solve various problems, leading to systematic conclusions. This concept leads to the conclusion that high school students aged 15-18 years should already be in the formal operational stage.

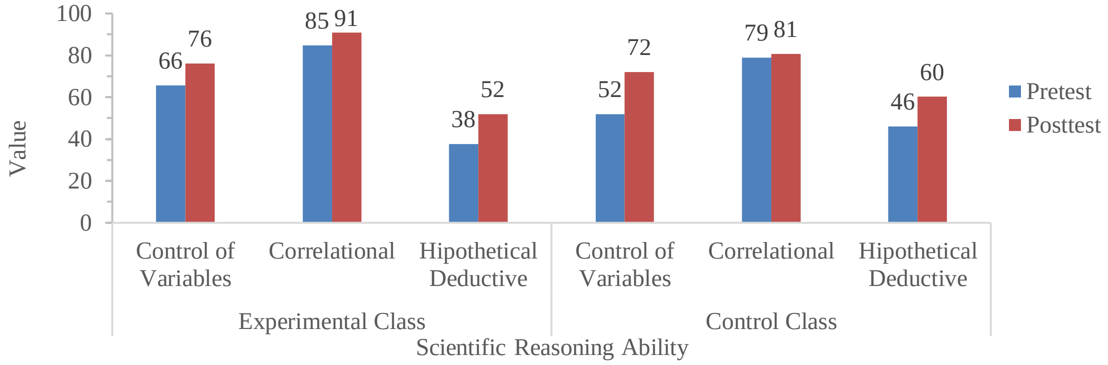

Figure 1. Average value of Scientific Reasoning ability

Average value of Scientific Attitude

The assessment of students' Scientific Attitude was conducted through the administration of a non-test instrument in the form of a questionnaire consisting of 10 positive statements and 10 negative statements with a rating scale of 1-5. The scores were then grouped into 5 stages of Scientific Attitude ability with a rating scale range of 20-100. The analysis results showed that the Scientific Attitude ability of students treated with PBL in the pre-intervention obtained an average score of 60 points, which falls into the "Moderate" category, while the control class scored 66 points, which falls into the "High" category.

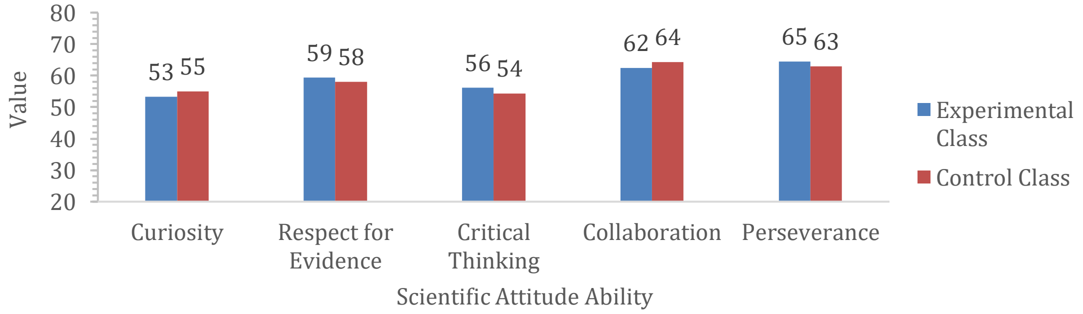

Figure 2. Pre-intervention average value of Scientific Attitude Ability

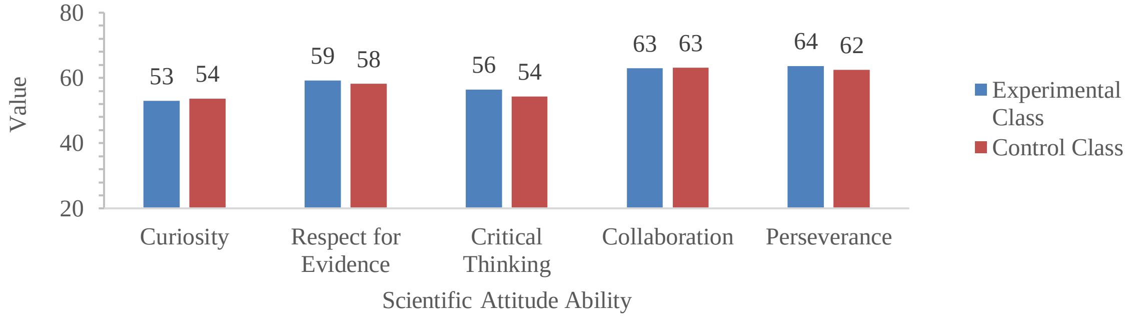

Figure 3. Post-intervention average value of Scientific Attitude Ability

The post-intervention results showed an average score of 69 points in the experimental class, which falls into the "High" category, while the control class scored 63 points, which falls into the "Moderate" category. The comparison of average scores in the Scientific Attitude ability results indicates a significant difference between the two sample classes.

Normality Test

The normality test in this study used the Shapiro-Wilk test to determine the distribution of research data on both variables. The results of the normality test on students' Scientific Reasoning and Scientific Attitude abilities are presented in the following table.

Table 1. Normality Test of Scientific Reasoning

Class	Shapiro-Wilk		
	Statistic	df	Sig.
Experimental Pre-test	.926	31	.035
Experimental Post-test	.929	31	.042
Control Pre-test	.872	31	.002
Control Post-test	.956	31	.227

Table 2. Normality Test of Scientific Attitude

Class	Shapiro-Wilk		
	Statistic	df	Sig.
Experimental Pre-	.943	31	.101
Control Pre-	.903	31	.009
Experimental Post-	.965	31	.393
Control Post-	.946	31	.121

Based on the results of the normality test, there are pre-test and post-test values in both the experimental and control classes that are not normally distributed. This is indicated by the presence of a significance value of less than 0,05.

Homogeneity Test

The homogeneity test in this study used the Levene statistical test. The results of the homogeneity test of the Scientific Reasoning Ability and Scientific Attitude data of students in each group are presented in the following table:

Table 3. Homogeneity Test of Scientific Reasoning

	Levene Statistic	df1	df2	Sig.
Pretest	.419	1	60	.520
Posttest	.091	1	60	. 764

Table 4. Homogeneity Test of Scientific Attitude

Levene Statistic		df1	df2	Sig.
Pre	.811	1	60	.372
Post	.611	1	60	.438

Table 3 shows that the variance of the pre-test and post-test data of the two sample classes in each variable is distributed homogeneously or equally.

Hypothesis Test of Variable 1

The hypothesis of variable 1, which states "there is an influence of the Problem-Based Learning model on students' Scientific Reasoning abilities", is tested using the Mann-Whitney test. This test was chosen based on the results of the normality test, which found that there was data variance that was not normally distributed, so that the hypothesis test would be carried out using a non-parametric test, namely the Mann-Whitney Test. The test results are presented in the following table.

Table 5. Hypothesis Test of Scientific Reasoning

Statistics	Post-test
Mann-Whitney U	429.500
Wilcoxon W	925.500
Z	-.728
Asymp. Sig. (2-*tailed*)	.466

The results showed that the application of the Problem-Based Learning model in this study did not have a significant effect on students' Scientific Reasoning abilities. The Asympt. Sig. (2-tailed) value for the Mann-Whitney hypothesis test showed a value of 0.466 or greater than 0.05. This value proves that H0, which reads "there is no influence of the Problem-Based Learning model on students' Scientific Reasoning abilities," is accepted for this research variable, and Ha, which reads "there is an influence of the Problem-Based Learning model on students' Scientific Reasoning abilities," is rejected.

The application of PBL in this study was expected to optimally improve students' Scientific Reasoning abilities, but the results did not show a significant improvement. One factor suspected to influence the results of this study is the inadequate time allocation for PBL implementation. Research shows that sufficient time allocation is crucial in PBL implementation to achieve the expected results. For example, research conducted by Karima [7] emphasizes the importance of adequate time in PBL implementation to achieve effective results.

Another factor suspected to influence the results of Scientific Reasoning abilities, which were not significantly different from the control class in this study, is the students' high academic background. Students with high academic abilities tend to have well-developed critical thinking and problem-solving skills, so the intervention of PBL implementation may not provide significant improvement compared to conventional learning methods. This is in line with Robaeni's findings [32], which show that learning approaches and academic background interact in influencing problem-solving abilities and student learning outcomes. This condition is referred to as the ceiling effect, which in this study may occur when students have already achieved high scores on the measured abilities, thus limiting the room for further improvement. In the context of this study, where students with high academic backgrounds may already have near-maximal Scientific Reasoning abilities, the application of PBL may not show significant differences compared to other learning methods. Further analysis proves that the average score of the experimental class falls into the formal reasoning stage category, while the control class is still at the transitional reasoning stage. This indicates that although the improvement produced by PBL is not statistically significant, this method still has a positive impact in pushing students towards a higher level of reasoning. Research by Lawson [25] emphasizes that formal reasoning is an important indicator of scientific thinking ability that develops through problem-based learning experiences. This is related to the concept of PBL, which emphasizes the development of skills, problem-solving, and independence in learning [33].

Hypothesis Test of Variable 2

The hypothesis of variable 2, which states "there is an influence of the Problem-Based Learning model on students' Scientific Attitude abilities", is tested using the Mann-Whitney Test on the basis that there is a data variance that is not normally distributed. The test results are presented in the following table.

Table 6. Hypothesis Test of Scientific Reasoning

Statistics	Post-test
Mann-Whitney U	270.500
Wilcoxon W	766.500
Z	-2.967
Asymp. Sig. (2-*tailed*)	.003

The results prove that the application of the Problem-Based Learning model in this study has a significant effect on students' Scientific Attitude abilities. The Mann-Whitney hypothesis test shows an Asymp. Sig. (2-tailed) value of 0.003 or less than 0.05. This value proves that H0, which reads "there is no influence of the Problem-Based Learning model on students' Scientific Attitude abilities," is rejected, and Ha, which reads "there is an influence of the Problem-Based Learning model on students' Scientific Attitude abilities," is accepted.

The application of the Problem-Based Learning model in this study has a positive effect on students' Scientific Attitude abilities. These findings are in line with the research results of Jamaluddin et al. [34], which prove that the Problem-Based Learning model is able to empower students' scientific attitude abilities. The PBL model trains students in problem-solving abilities through a series of learning processes. Each stage in PBL can facilitate students to develop attitudes of curiosity, appreciation for data/facts, critical thinking, creativity, openness, cooperation, perseverance, and sensitivity to the surrounding environment. This is in accordance with the opinion of Dewi et al. [35], who state that the scientific attitude formed in learning will provide students with experience to recognize and understand the nature of interactions in the learning process.

Through this research, it was found that problem-based learning models have a considerable probability of influencing students' scientific literacy abilities, especially in the aspect of science as an attitude. One important point that needs to be emphasized in problem-based learning is that the time allocation required for its implementation is no less than that of other similar learning models, so adequate time availability needs to be considered. Supporting factors, such as a conducive learning environment, are important external factors to consider in implementing this learning model.

Conclusion

Based on the research results, it can be concluded that although the Problem-Based Learning model has a significant effect on students' Scientific Attitude abilities, its impact on students' Scientific Reasoning abilities is not statistically significant in the context of this study. The research results show that the experimental class obtained an average score of 75 points (formal), and the control class obtained a score of 72 points (transitional) on the Scientific Reasoning aspect. On the Scientific Attitude aspect, the experimental class obtained a score of 69 (High) and the control class obtained a score of 63 (Moderate). Additionally, the Asympt. Sig. (2-tailed) value on the Scientific Reasoning aspect is greater than 0.05, which is 0.466, while on the Scientific Attitude aspect, it is 0.003 or less than 0.05. These results can be influenced by external factors that cannot be fully controlled during the research process, so supporting factors such as adequate time allocation, student conditions, and variation in teaching methods are crucial to be further considered to optimize the impact on scientific literacy abilities, particularly on Scientific Reasoning and Scientific Attitude.

Author's Contribution

Ira Yasmin: contributed to the conceptualization and design of the research, data collection, data analysis, and writing of the article. A. Wahab Jufri, Kusmiyati, and I Wayan Merta: supervised the entire research process, provided theoretical insights, and reviewed the final version of the paper. All authors have read and approved the final manuscript.

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