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THE EFFECT OF THE PROBLEM BASED LEARNING ON MATHEMATICAL REASONING AND PROOFING ABILITY IN TERMS OF LEARNING STYLE

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Abstract

Mathematics is the main foundation at various levels of education so that students need to be equipped with mathematics in order to have the ability to reason, think logically, systematically and critically in dealing with various problems. There are several factors that cause low reasoning abilities in schools, some of which are the use of learning methods or models while in class. An appropriate learning model for students can improve mathematical reasoning and proving abilities. Learning styles which are divided into three, namely visual, auditory and kinesthetic can also be a factor in low reasoning abilities. The purpose of this study is to identify the impact of the Problem Based Learning model on mathematical reasoning and proof skills, taking into account variations in learning styles. The population in this study were all 8th grade student at SMP Negeri 1 Gatak. The samples taken were two classes taken randomly using simple random sampling technique. This research is a quantitative research with a quasi experiment. The instruments used in this study consisted of a learning style questionnaire, pretest and posttest. The findings from this study are as follows: 1) The use of the Problem Based Learning (PBL) model has a significant impact on students' abilities in mathematical reasoning and proof; 2) Learning style has no effect on students' mathematical reasoning and proving abilities; 3) No interaction was detected between learning models and learning styles in influencing students' mathematical reasoning and proving abilities.

Keywords: problem based learning, learning style, reasoning ability, mathematical proof

Abstrak

Matematika merupakan fondasi utama dalam berbagai jenjang pendidikan sehingga siswa perlu dibekali dengan ilmu matematika agar memiliki kemampuan bernalar, berpikir logis, sistematis dan kritis dalam menghadapi berbagai permasalahan. Terdapat beberapa faktor yang menyebabkan rendahnya kemampuan penalaran di sekolah, beberapa diantaranya adalah penggunaan metode atau model pembelajaran yang selama di kelas. Model pembelajaran yang sesuai bagi siswa dapat meningkatkan kemampuan penalaran dan pembuktian matematis. Gaya belajar yang dibagi menjadi tiga yaitu visual, auditorial dan kinestetik juga dapat menjadi faktor rendahnya kemampuan penalaran. Maksud dari penelitian ini adalah untuk mengidentifikasi dampak model Problem Based Learning terhadap keterampilan penalaran dan pembuktian matematis, dengan mempertimbangkan variasi gaya belajar. Populasi dalam penelitian ini adalah seluruh siswa kelas VIII di SMP Negeri 1 Gatak. Sampel yang diambil sebanyak dua kelas yang diambil secara acak menggunakan teknik *simple random sampling*. Penelitian ini adalah penelitian kuantitatif dengan *quasi experiment*. Instrumen yang dipergunakan dalam penelitian ini terdiri dari angket gaya belajar, pretest dan postest. Temuan yang dicapai dari penelitian ini adalah sebagai berikut: 1) Penggunaan model Problem Based Learning (PBL) memberikan dampak yang signifikan terhadap kemampuan siswa dalam penalaran dan pembuktian matematis; 2) Gaya belajar tidak memiliki pengaruh terhadap kemampuan penalaran dan pembuktian matematis siswa; 3) Tidak ada interaksi yang terdeteksi antara model pembelajaran dan gaya belajar dalam mempengaruhi kemampuan penalaran dan pembuktian matematis siswa.

Kata kunci: problem based learning, kemampuan penalaran, pembuktian matematis, gaya belajar

INTRODUCTION

The role of mathematics in daily activities and surrounding life has in common with a branch of science that functions as a basic structure. It is very important to realize that each individual is deeply intertwined with mathematical cognition which is inherent in their daily

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life (Anugrah & Pujiastuti, 2020). Students need to be equipped with mathematics in order to have the ability to reason, think logically, systematically, critically, carefully and be objective and open when faced with various problem scenarios (Kasri, 2018; Kurnia Putri et al., 2019; Wahyuningrum & Rumanta, 2022).

Among the several basic goals that exist, there is one fundamental goal in pursuing mathematics education, namely the cultivation and improvement of reasoning abilities. According to the NCTM (National Council of Teachers of Mathematics), students are expected to demonstrate proficiency in five major learning process standards. The standards cover problem solving, reasoning and proof, communication, connections, and representation, serving as important benchmarks for students' mathematical development. The process of learning mathematics can develop reasoning abilities, thus training students to use logical reasoning in solving mathematical problems and developing mindsets and developing creativity in learning (Khaeroh et al., 2020; Kusumawardani et al., 2018)

Mathematical reasoning ability is the basis of mathematics learning that needs to be considered (Rahmawati & Tsurayya, 2023). The ability to logically solve mathematical problems is closely related to students' reasoning abilities (Pradana & Murtiyasa, 2020). Indicators for measuring mathematical reasoning ability have been described in the regulation of the Directorate General of National Education (Dirtjen Diknas) No. 506/C/PP/2004, which includes: formulating hypotheses, manipulating, concluding, organizing evidence, providing arguments or evidence against solutions, drawing conclusions from statements, evaluating the validity of arguments and identifying patterns or characteristics to make generalizations. Proof in reasoning is supported by the National Council of Teachers of Mathematics (NCTM) which also states that proof is included in reasoning in the "Reasoning and Proof" section, it is stated that students should have the ability to identify reasoning and proof as basic components of mathematics, formulate conjectures and verify validity (Herawati & Amelia, 2021), constructing and evaluating arguments and mathematical evidence and applying various forms of reasoning and proof techniques.

Based on interviews with mathematics teacher for 8th grade SMP Negeri 1 Gatak, students' mathematical reasoning and proving abilities related to problem solving are still relatively lacking. Factors that influence this include students who are not used to processing

their reasoning abilities in working on mathematical problems, the problems they work on are not much different from the questions that have been exemplified by the teacher, they do not have the motivation to polish their reasoning abilities. Low reasoning can also be caused by the learning model implemented in class (Maskar et al., 2020; Nurjanah et al., 2022). The use of appropriate learning models is proven to help improve students' reasoning not only in the teaching and learning process but also in everyday life. Problem Based Learning has been identified as a learning model that is potentially effective in improving reasoning abilities (Marfu, 2022) where learning is centered not on the teacher but on students (Chiang & Lee, 2016) so that there is a need for a change in the role of the teacher in the classroom, from teachers who only provide material to become facilitators in learning (Maryati, 2018; Murtiyasa, 2015). As for some of the characteristics of Problem Based Learning based on Rusman (2010) are issues that are the main focus in the learning process, utilizing real situations as problems, testing students' knowledge, attitudes and skills, using various sources of knowledge, and involving evaluation and reflection on student experiences and learning Student learning styles are also a factor that can influence reasoning abilities (Nurhayati & Subekti, 2017; Sukmawati et al., 2023). Learning style is a consistent feature in the learning process because it reflects fixed and consistent characteristics in how students absorb information (Amin & Suardiman, 2016; Wilujeng & Sudihartinih, 2021). Each individual has a unique learning style, therefore, the speed of understanding each student's lessons also varies, some of them are able to grasp lessons quickly and some are not (Rahmi & Samsudi, 2020; Zulfah et al., 2021). DePorter and Hernacki (2000) mention that learning styles are divided into three, namely visual, auditory and kinesthetic learning styles. Each learning style has unique strengths that can support a person's learning abilities (Erawati & Purwati, 2020). Individuals who learn with a visual style tend to focus attention on the use of the sense of sight during the learning process. They used to think in pictures and learned better to use visualization. While those who have an auditory learning style rely on hearing abilities to absorb learning material. They usually easily remember something they catch by ear. Meanwhile, students with a kinesthetic learning style need to physically interact with learning objects or materials to facilitate information recall. They learn through a direct and active approach. (Hasanudin & Fitrianingsih, 2019; Hendriana, 2018; Ophilia Papilaya & Huliselan, 2016; Restianim et al., 2020).

Several previous studies, such as research by (Khaeroh et al., 2020; Wahyuningrum & Rumanta, 2022) Problem Based Learning had a significant impact on mathematical reasoning abilities. Furthermore, in a study by (Sukmawati et al., 2023), it was revealed that there is a moderate level of correlation between learning styles and students' mathematical reasoning abilities. Based on some of the things that have been described above, further research is needed on the application of Problem-Based Learning to reasoning abilities and mathematical proof by considering the learning styles of students at the junior high school level. This study aims to determine: 1) whether PBL affects mathematical reasoning and proving abilities; 2) whether learning styles affect mathematical reasoning and proving abilities; and 3) how the interactions between learning models and learning styles affect mathematical reasoning and proving abilities.

METHODS

In this study, a quantitative approach was used which was carried out at SMP Negeri 1 Gatak in the period from April to June 2023. Quantitative research is a systematic method that is used to examine certain phenomena by involving the collection of data that can be measured and analyzed using statistical techniques, mathematics, and computing (Ramdhan, 2021). The same thing was explained by Sugiyono (2003) in (Nugroho, 2018), which revealed a quantitative approach in research methodology to produce data presented in numerical form, usually derived based on findings from various tests. This study used a quasi-experimental type with a non-equivalent control group design. The 2x3 factorial design is presented in the table 1.

Table 1. Table of Research Design

Learning Approach (A)	**Learning Style (B)**		
	Visual (B_1)	**Auditory (B_2)**	**Kinesthetic (B_3)**
Problem-Based Learning (A_1)	A_1B_1	A_1B_2	A_1B_3
Conventional Learning (A_2)	A_2B_1	A_2B_2	A_2B_3

The population that became the focus of the research was all of the VIII grade students at SMP Negeri 1 Gatak. Samples were taken by simple random sampling from the population, with 60 students who would be divided into experimental group and control group. This study uses various instruments, including test instruments and learning style surveys. The test instrument contains four questions designed to evaluate participants' reasoning abilities and

mathematical abilities. The learning style questionnaire contains 30 statements to classify the main learning styles into three categories: visual, auditory, and kinesthetic learning styles. The data collection method in this study involved distributing learning style questionnaires to two different groups, namely the experimental group and the control group. Prior to implementing Problem-Based Learning (PBL) learning or conventional learning methods, students will be given a pre-test. After the learning intervention is completed, students will be given a post-test to evaluate the achievement of their learning outcomes. Data analysis in this study applied the normality test and homogeneity test as prerequisite tests, and a two-way analysis of variance (ANOVA) was carried out to investigate the relationship between the variables studied.

RESULTS AND DISCUSSION

This study consisted of two different groups, each of which received a different intervention. The experimental group is given treatment by applying Problem Based Learning and the control group is given treatment by conventional learning. The pretest was held at the beginning of the study as an effort to assess participants' initial knowledge or skills. Furthermore, the established learning model is implemented in each class. Finally, the investigation ends with the administration of a post-test to evaluate the progress or performance of the participants after applying the learning model mentioned above.

The table 2 presents data relating to student learning styles, which have been obtained through administering a questionnaire.

Table 2. Table of Research Design

Learning Approach	Learning Style			Total
	Visual	Auditory	Kinesthetic	
Problem-Based Learning	21	9	0	30
Conventional	24	5	1	30
Total	45	14	1	60

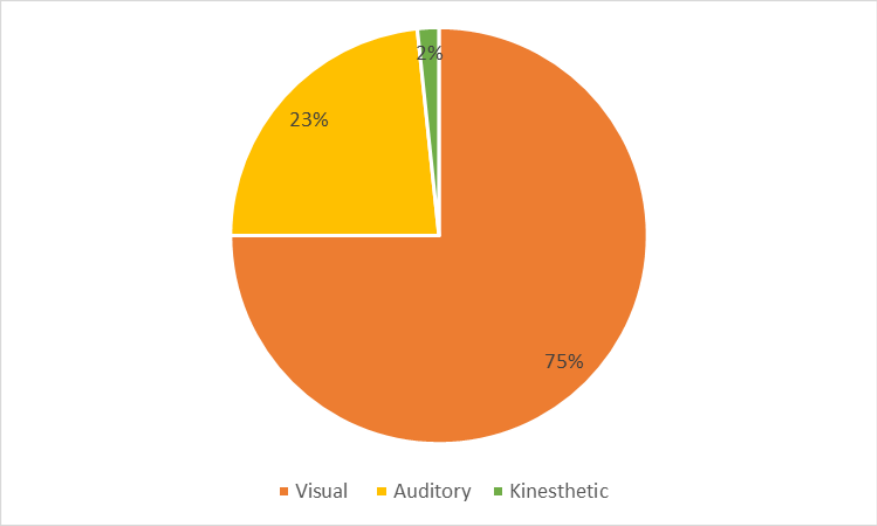

Figure 1. Student Learning Styles Diagram

The majority of students have a visual learning style as the most common. It can be seen that both in the experimental class and the control class, students who have a visual learning style dominate compared to other learning styles. Research (Ayu Rahmayani et al., 2023; Kurniawan & Hartono, 2020; Sukmawati et al., 2023) also presents data showing that there are more students with a visual learning style than other learning styles.

During the pre-test and post-test, students were asked to complete questions according to the indicators of mathematical reasoning and proving abilities. The work on the pre-test questions was carried out before the implementation of the learning model in each class while the post-test work was carried out after the application of the PBL model, with the aim of ascertaining the impact of implementing this learning model. Next, the results of descriptive statistics relating to the pre-test and post-test scores observed in both classes are presented.

Table 3. Table of Descriptive Statistics of Mathematical Reasoning and Proofing Ability

Statistic	Problem-Based Learning		Conventional	
	Pre-Test	Post-Test	Pre-Test	Post-Test
Total of Sample	30	30	30	30
Range	62	39	70	47
Minimum Score	23	46	15	15
Maximum Score	85	85	85	62
Mean	52,77	65,00	47,20	39,13
Standard Deviation	18,135	12,295	19,345	12,632
Variants	328,875	151,172	374,234	159,568

Based on the table 3, it can be seen that students who take part in learning by implementing the Problem-Based Learning (PBL) model show a level of reasoning ability and mathematical proving that tends to be qualified when compared to students who take conventional learning models.

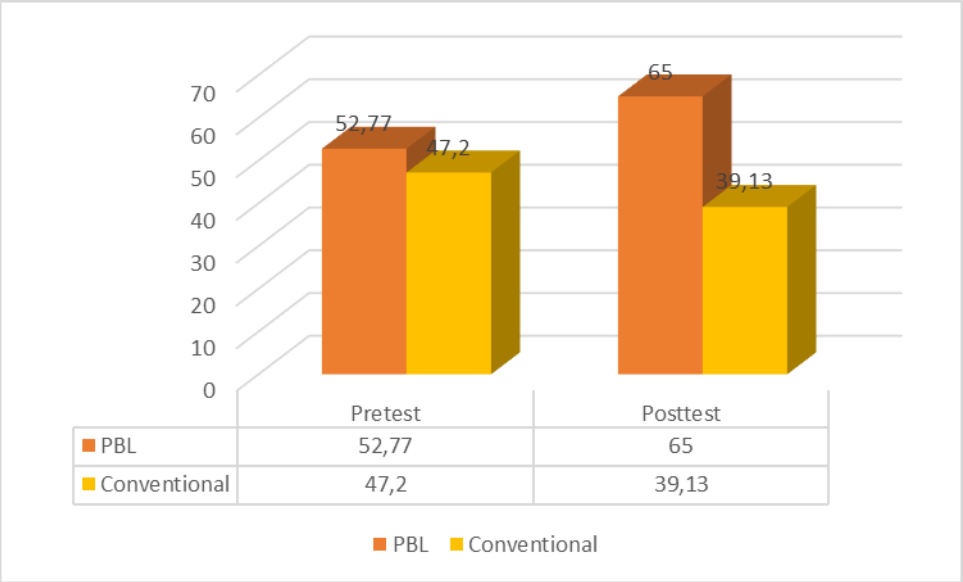

Figure 2. Diagram of Comparison of Mean Pre-test and Post-test Scores

Statistical analysis was applied through the normality test and homogeneity test as an initial assessment, followed by a two-way ANOVA test. The table 4 presented show the results obtained from applying SPSS Statistics for data processing.

Table 4. Table of Normality Test Results

Class	N	Sig.	Result
Pre-test of PBL Class	30	0,201	Normal distribution
Post-test of PBL Class	30	0,052	Normal distribution
Pre-test of Conventional Class	30	0,115	Normal distribution
Post-test of Conventional Class	30	0,059	Normal distribution

The normality test is carried out through the application of the Shapiro-Wilk Normality Test with a significance level of 5%. According to statistical conventions, it is considered that the data is normally distributed when the significance value (Sig.) exceeds the limit of 0.05. Based on the data listed in the table 4, the PBL class pre-test score was 0.201, while the PBL class post-test score reached 0.052. On the other hand, the conventional class pre-test score was recorded at 0.115, and the conventional class post-test score reached 0.059. So that the

test data from the two classes are normally distributed. Therefore, the conclusion that can be drawn is that both the PBL class and the conventional class come from populations with normal distribution. After carrying out the normality test, the next step is to run a homogeneity test to measure the extent to which the two groups have similar levels of variance.

Table 5. Table of Homogeneity Test Results

Based on Mean	Sig.	Result
Pre-test	0,386	Homogeneous
Post-test	0,905	Homogeneous

The homogeneity test for the two variables was carried out through the Homogeneity of Variance Test with a significance level of 5%. This means that the data is considered homogeneous if the significance value (Sig.) exceeds 0.05. Based on the information in the table 5, the test results on the pre-test data showed a significance value of 0.386, and the post-test data had a significance value of 0.905. Both of these significance values exceed the threshold of 0.05. Thus, it can be stated that the data variation is homogeneous. Next, it is continued by running a two-way ANOVA test to test the hypothesis.

Table 6. Table of Two-way Anova Test Results

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Learning Approach (A)	5346,849	1	5346,849	36,456	0,000
Learning Style (B)	341,241	2	170,621	1,163	0,320
Interaction (AB)	420,820	1	420,820	2,869	0,096

From the information listed in the table 6, the test results show several values. The significance of the learning model is 0.000, this value is lower than 0.05, which means the null hypothesis (H_{0A}) is rejected. So there are differences in reasoning abilities and mathematical proving between students who study with the Problem Based Learning model and students who study with conventional learning models. This finding is in line with research conducted by (Komala et al., 2017). The research indicates that there are differences in reasoning abilities between students who follow the Problem Based Learning learning model and those who do not follow the model. This difference is explained by the fact that in classes that apply Problem Based Learning, students are actively involved in solving problems and are required to use higher thinking skills.

The experimental class that used the Problem-Based Learning (PBL) model obtained an average score of 62,556 on tests of reasoning and proof abilities. In contrast, the control class that applied conventional learning obtained an average score of 38,947 on the same test. The results show that the average value of the experimental class exceeds that of the control class, indicating that the use of the Problem Based Learning (PBL) model produces much more positive results compared to conventional learning. Therefore, it can be concluded that the application of the Problem Based Learning method is one of the strategies to improve the quality of reasoning and proving abilities in mathematics.

The results of the next test involve learning styles with a significance value of 0.320. This value exceeds 0.05, which indicates that there is no significant effect between mathematical reasoning and proving abilities and learning styles. In other words, there is no significant relationship between mathematical reasoning and proving abilities with visual, auditory, or kinesthetic learning styles in students. Similar findings were recorded in research conducted by (Araiku, 2022) on SMP Negeri 3 Gelumbang students. This study shows that students' learning styles do not have a significant effect on mathematics learning achievement, with the factors that influence this are not including learning objectives in the instruments tested.

The results of testing the interaction between learning models and learning styles show a significance value of 0.096, where the value exceeds 0.05. This indicates that there is no significant interaction between learning models and learning styles on mathematical reasoning and proving abilities. This is shown through the graph in Figure 3, where there is no interaction between these two variables.

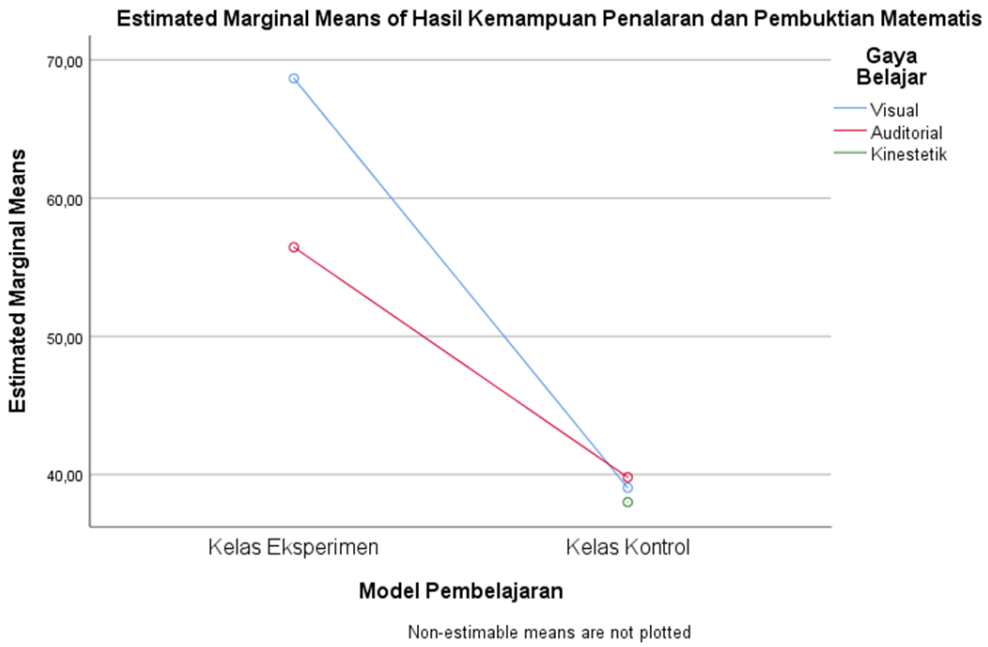

Figure 3. Graph of Interaction Between Learning Models and Learning Styles

In other words, collaboration between learning models and learning styles does not have a significant effect on students' mathematical reasoning and proof abilities. Thus, through the learning model used, whatever learning style a student has does not affect their mathematical reasoning and proof abilities. This finding is in line with the results of research conducted by (Khaeroh et al., 2020) which also showed that there was no significant interaction between learning models and learning styles on students' mathematical reasoning abilities.

CONCLUSION

From the results of the research and analysis described above, it can be concluded that there are differences in mathematical reasoning and proving abilities between students who receive learning through the Problem Based Learning model and those who learn using conventional teacher-centered methods. However, no effect was detected between visual, auditory, or kinesthetic learning styles on the students' mathematical reasoning and proving abilities. In addition, there is no significant interaction between the application of learning models and student learning styles in terms of their impact on mathematical reasoning and proving abilities.

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