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Effect of Implementing Differentiated Learning Based on Learning Style on Abilities in Mathematical Problem-solving

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This research was motivated by the low mathematical problem-solving abilities of State High School 4 students in Tanjung Jabung Barat-Indonesia. This research aims to determine the effect of implementing differentiated learning based on learning styles on students' mathematical problem-solving abilities using a Pretest and Posttest Control Group Design, namely that there is one group, each chosen randomly. The population of this research is all students in class. In this research, the sample used was 116 students divided into one class. The sample was determined using the Random Sampling technique. The data collection techniques used in this research were observation and tests of mathematical problem-solving abilities. This research indicates that differentiated learning based on learning styles effectively influences students' mathematical problem-solving skills. Thus, learning styles can be used as an alternative in improving problem solving abilities, especially in the context of mathematics learning.

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Keywords: Differentiated learning based; learning style; mathematical problem solving.

1. INTRODUCTION

Education in Indonesia has experienced many changes in the use of technology and the latest learning methods to increase students' enthusiasm for learning. The government, teachers, and schools are now trying to do the best learning so that students are enthusiastic about participating in learning activities in class. The independent curriculum is one form of the latest curriculum change effort that is fun and adapts to each student. Differentiated learning is now an important thing that must be implemented in schools to meet the needs of these students [1]. Differentiated learning itself allows teachers to see learning from various perspectives. Differentiated learning is a cyclical process of learning about students and responding to their learning based on differences. Differentiated learning is not individualized learning. However, it tends to be learning that accommodates students' strengths and learning needs with independent learning strategies. Differentiated learning views students as different and dynamic [2].

Differentiated learning is learning that recognizes that each student has different abilities and desires. Therefore, in the context of teachers, differentiated learning requires teachers to be able to explore the abilities and desires of students and adapt them to the learning models carried out by the teacher. This is in line with Defitriani's [3] opinion that teachers as leaders in the learning process are required to be able to embrace these differences in characteristics and develop the potential of each student. Apart from that, it is also stated that differentiated learning is learning that is tailored to student needs with the aim of maximizing the potential of each student. DI is structured based on student differences which include learning readiness, interests and learning profiles which are designed by differentiating content, processes and products. This was also mentioned by Husni (2013) that in differentiated learning there are 3 aspects that can be differentiated by teachers so that students can understand the lesson material they are studying, namely aspects of the content that will be taught, aspects of the process or meaningful activities that will be carried out by the participants. Students in class, the assessment aspect is in the form of product creation which is carried out at the end which can measure the achievement of learning objectives. In the context of students, differentiated learning allows them to learn according to their abilities and desires. This situation provides a great opportunity for students and teachers to be more successful in their own learning tasks.

According to Harahap & Surya [4] and Kreibich et al. [5], problem-solving abilities are an essential part of the mathematics curriculum because, in the learning process, they can solve them, and students can gain experience using the knowledge and skills they already have to apply to solving routine problems. Problem-solving is a competency students demonstrate in understanding and choosing a solution strategy to solve a problem. Students' ability to solve problems can be seen from several Polya problem-solving steps, namely: (1) understanding the problem, (2) making a plan, (3) implementing the plan, and (4) checking again Marulis & Nelson [6].

According to Saodah et al. [7]. The ability to solve problems is influenced by several factors, one of which is metacognition. Metacognition is one of the innovative learning skills of the 21st century which involves high-level cognitive processes including thinking about knowledge and how to obtain knowledge through a reflective process. Meanwhile, Kusmawan et al. [8] found that problem solving abilities are closely related to creative thinking abilities. Thus it can be understood that problem solving ability is actually an ability or skill that can be trained. This is in line with the explanation of Izzah et al. [9] problem-solving abilities can be trained in learning to develop analytical, deductive and inductive thinking skills to solve problems related to environmental events. However, the problem solving abilities of each student in the learning process are different, some are fast and some are slow. One factor that is thought to strongly influence the development of students' problem-solving abilities is learning style.

According to Sakti et al. [10], student learning style is the way students react and use the stimuli they receive in the learning process. An appropriate learning style is the key to a person's success in learning. In learning activities, students need help and direction to recognize the learning style that suits them, so that learning goals can be achieved optimally. Kusumasari & Nugraheni [11] stated that learning style is one of the factors that can influence learning success.

Rafiska & Susanti [12] state that learning styles can be defined as permanent ways used by students to take in stimulus and information, ways of thinking, remembering and working on questions. Thus it can be understood that student learning styles play a role in improving problem solving abilities, including in terms of learning mathematics.

Students' understanding of mathematical problem-solving will impact other learning objectives, and the learning process will become less active. The low ability of students to solve mathematical problems is one of the factors that causes them to dislike and avoid mathematics because of the difficulty in solving the given problems. So, efforts that can be made to overcome this problem are to create a learning atmosphere suitable for students' learning styles, namely auditory, visual, and kinesthetic, so that learning objectives can be achieved effectively. Every student has a different learning style.

Learning styles are students' habits in processing information experiences and students' habits in treating the experiences they have. If students are familiar with their learning styles, they can take essential steps to help them learn faster and more efficiently, supporting the learning goals. Different learning styles will undoubtedly influence students' mathematical problem-solving abilities in learning activities. It is reinforced by Omar [13] opinion that several factors can affect students' problem-solving skills in mathematics. These factors arise because each individual is different. Individual differences include intelligence, ability to think logically, creativity, cognitive style, personality, values, attitudes, and interests. The attitude referred to here is related to the student's learning style in the classroom. Based on the explanation above, this research will discuss the application of differentiated learning based on learning styles. This research aims to find out and examine the influence of differentiated learning based on learning styles on students' mathematical problem-solving abilities.

2. RESEARCH METHODS

This research aims to determine the effect of differentiated learning based on learning styles on problem solving abilities in the context of mathematics learning. Thus, the main question that will be answered in this research is whether there is an influence of differentiated learning on students' problem solving abilities in the context of mathematics learning? The design in this research is a Pretest and Posttest Control Group Design with non-equivalent groups. The population of this research is all class X students at State High School 4 Tanjung Jabung Barat, totaling 116 students divided into four classes. This research was conducted using the Simple Random Sampling technique. The sample consisted of 30 students taken for one class to compare before and after the experiment. Class Meanwhile, data collection uses research instruments in the form of test questions, and data analysis is quantitative/statistical with the aim of testing predetermined hypotheses [14-16].

This research consists of two variables, namely the independent variable and the dependent variable. The independent variables in this research are visual learning style, auditory learning style, and kinesthetic learning style, while the dependent variable is mathematical problem-solving ability. This research uses a Pretest and Posttest Control Group Design. This research uses statistical material, namely mean, mode, and Median. In the group, a pretest was carried out. An experiment was conducted, and finally, a posttest stage was carried out to see the students' mathematical problem-solving results.

2.1 The Research Instruments Used Are

2.1.1 Problem-solving ability test questions

The mathematical problem-solving ability test instrument consists of two pretest and posttest questions. The pretest questions were used to assess students' initial mathematical problem-solving abilities before the Treatment was carried out. Then, the posttest questions were carried out after the Treatment was completed. The test questions given are in the form of essay questions. Through this test in the form of a description, students' progress can be identified to see the results of students' mathematical problem-solving abilities. Before use, the questions are first tried out using item analysis, namely as follows:

2.2 Content Validity Test

The content validity test was tested by experts who are postgraduate lecturers at Jambi University. Validity testing aims to see the reliability or validity of an instrument.

Table 1. Research design

Class	*Pretest*	Treat	*Posttest*
Experiment Group	0_2	X	0_4

Information:
02 = Pretest experimental group
X = Treatment with differentiated learning based on learning style
04 = Experimental group posttest

2.3 Reliability of Testing Questions

Reliability is the consistency/stability of scores on a research instrument on the same individual and given at different times. According to Hodge [16] the alpha formula is used to determine the reliability of an instrument.

2.4 Difficulty Level

A test item's difficulty level is the opportunity to answer questions correctly from a test item at a certain level of ability. The difficulty of a test item is the average score obtained by students and is expressed in the form of a proportion of 0.00 to a proportion of 1.00.

2.5 Different Power

The similarity of the items of an instrument must measure the same thing and show the same trend.

The research design can be seen in Table 1.

The collected data was then analyzed using descriptive statistical analysis and inferential analysis, which aims to determine whether the application of differentiated learning based on learning styles affects the mathematical problem-solving abilities of the class. Before data processing is carried out, a prerequisite test is first carried out; here is the explanation:

1. Normality Test

The normality test is one of the prerequisite tests for fulfilling the assumption of normality in parametric statistical data analysis. It is used to see whether the sample is normally distributed or not. In this study, the normality test used Kolmogorov Smirnov with the help of SPSS software.

2. Homogeneity Test

The homogeneity test is conducted to see whether the sample group has homogeneous variants. This test was carried out using the Levene test with the help of SPSS.

3. Hypothesis Testing

The hypothesis test used in this research is the t-dependent test. The dependent t-test is used to compare the means of two paired groups.

3. RESULTS

This research consisted of one group selected by Random Sampling and composed of 30 students in the class. Next, a posttest was given to find out whether there were differences in scores between the groups before and after the Treatment was applied. The instrument used in this research is two problem-solving ability test questions for pretest and posttest in the form of descriptions whose validity was previously tested by experts. Before carrying out data analysis, the collected data is first tested for normality and homogeneity as below:

Table 2. Pretest data normality test

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Learning Style	Statistic	Df	Sig.	Statistic	Df	Sig.
Score	Visual	.147	11	.200*	.960	11	.770
	Auditory	.211	7	.200*	.948	7	.709
	Kinesthetic	.184	12	.200*	.913	12	.235

*. It is a lower bound of the true significance
a. Lilliefors Significance Correction

Based on the decision-making criteria, if the significance value is ≥ 0.05, then H_1 is accepted, and if the significance value is <0.05, then H_1 is rejected. The table shows that the significance value for the experimental and control classes is ≥ 0.05, so it can be concluded that H_1 is accepted, so the pretest data has a normal distribution. After carrying out the normality test, the pretest data was tested for homogeneity

Table 3. Pretest data homogeneity test

Test of Homogeneity of Variances					
		Levene Statistic	**df1**	**df2**	**Sig.**
Score	**Based on Mean**	.166	2	27	.848
	Based on Median	.064	2	27	.938
	Based on the Median and with adjusted df	.064	2	25.317	.938
	Based on trimmed mean	.163	2	27	.850

Based on the decision-making criteria, if the significance value is ≥ 0.05, then H_1 is accepted, but if the significance value is <0.05, then H_1 is rejected. Based on the table above, it can be seen that the significance value is ≥ 0.05, so H_1 is accepted; in other words, the pretest data has a homogeneous variance. Next, prerequisite tests are carried out for posttest data

Table 4. Posttest data normality test

Tests of Normality							
	Learning Style	**Kolmogorov-Smirnov[a]**			**Shapiro-Wilk**		
		Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Posttest	Visual	.224	11	.130	.858	11	.054
	Auditory	.238	7	.200*	.807	7	.049
	Kinesthetic	.178	12	.200*	.886	12	.106
*. It is a lower bound of the true significance.							
a. Lilliefors Significance Correction							

Based on the decision-making criteria, if the significance value is ≥ 0.05, then H_1 is accepted, and if the significance value is <0.05, then H_1 is rejected. The table shows that the significance value for the experimental and control classes is ≥ 0.05, so it can be concluded that H_1 is accepted, so the pretest data has a normal distribution. After carrying out the normality test, the posttest data was tested for homogeneity

Table 5. Posttest data homogeneity test

Test of Homogeneity of Variances					
		Levene Statistic	**df1**	**df2**	**Sig.**
Posttest	Based on Mean	.285	2	27	.754
	Based on Median	.322	2	27	.727
	Based on the Median and with adjusted df	.322	2	20.884	.728
	Based on trimmed mean	.298	2	27	.745

Based on the decision-making criteria, if the significance value is ≥ 0.05, then H_1 is accepted, but if the significance value is <0.05, then H_1 is rejected. Based on the table above, it can be seen that the significance value is ≥ 0.05, so H_1 is accepted; in other words, the posttest data has a homogeneous variance. After carrying out the prerequisite tests above, a hypothesis test will be carried out using the t-dependent test in this research

4. DISCUSSION

In the discussion section, the researcher will discuss several results of data analysis that have been obtained. The discussions carried out include 1) interpretation of research results, 2) comparison of research results with theory, and 3) comparison of research results with relevant research. The results of data analysis carried out using SPSS version 25 show a significant influence of differentiated learning based on learning styles. Each class gets a significance value smaller than 0.05, which shows a substantial influence between variables. Thus, applying differentiated learning based on learning styles effectively improves students' problem-solving abilities.

The different influences of the application of differentiated learning based on learning styles on students' mathematical problem-solving abilities can be explained through students'

approaches, interactions, and involvement in the learning process [17,18]. In differentiated learning based on learning styles, students are grouped using their respective learning styles. The first group was taught with a visual style, where the teacher distributed illustrative images of the material. In contrast, students with auditory and kinesthetic learning styles read the material in printed books. Learning with an auditory learning style is taught directly, where students listen to explanations about the material well, and finally, students with a kinesthetic learning style are given track props for the material being taught Houwer, [18], Dale et al., [19]. This approach allows students to understand concepts in depth and develop problem-solving skills by utilizing their discoveries. Differentiated learning based on learning styles can help all students in learning where teachers can increase awareness of student's abilities so that all students can achieve learning goals.

The application of differentiated learning based on learning styles is a lesson that aims to maximize the learning process for students and teachers to achieve learning goals. Learning that suits students' learning styles fosters interest and motivation to be mentally and physically active in learning activities and can help students optimize learning. Students are accustomed to thinking critically, logically, and systematically when working on LKPD, and students are required to search for information themselves and discuss it with friends or read books. Compared to conventional learning (without differentiated learning styles), the teacher in the classroom dominates, causing students to become more passive and less active in the learning process.

Several things cause differentiated learning based on learning styles to improve students' problem-solving abilities, including because students are taught based on their respective learning styles so that students are enthusiastic about learning. Apart from that, students do not easily forget about lesson material because students construct their lesson material. Constructivist learning theory allows students to think, solve problems, look for ideas, and make decisions.

Differentiated learning based on learning styles provides more significant opportunities for students to develop deep understanding, flexible problem-solving skills, and intrinsic motivation for mathematics. Students will understand better and be able to apply what they learn in all situations (Sari et al., 2023). Students should be directly and actively involved so they can understand the concept of the lesson being taught and remember it longer.

Table 6. Dependent T-test

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	Df	Sig. (2-tailed)
Pair 1	Pretest– Posttest of Visual	-41.455	17.131	5.165	-52.963	-29.946	-8.026	10	.000
Pair 2	Pretest- Posttest of Auditory	-38.571	15.757	5.956	-53.144	-23.999	-6.476	6	.001
Pair 3	Pretest- Posttest of Kinesthetic	-43.083	15.288	4.413	-52.797	-33.370	-9.762	11	.000

Based on decision-making, where is the Sig value? (2-tailed) ≥ 0.05, then there is no significant difference; conversely, if the Sig. (2-tailed) < 0.05, so there is a substantial difference in the pretest and posttest data. As seen from the table above, the dependent sample t-test shows that for group I, the value of Sig. (2-tailed) namely 0.000, group 2 Sig value. (2-tailed) which is 0.001, and class group 3 also gets a Sig value. (2-tailed) 0.000. In this way, it is shown that groups I, 2, and 3 got a Sig value. (2-tailed) which is the same, namely <0.05. Because it is known that the Sig value. (2-tailed) For the three groups, the difference is smaller than 0.05, so it can be concluded that there is a significant or real influence between the application of differentiated learning based on learning styles and students' mathematical problem-solving abilities. After the hypothesis test, the results of the class's mathematical problem-solving abilities can be seen

The findings of the analysis show that differentiated learning is influenced significantly by learning styles. This is because the syntax in each learning style gives students learning Treatment and uses LKPD (Student worksheet), which is also based on the learning syntax and contextual or actual problems. The results of this research are strengthened by other findings from the study of Basuki & Wijaya, [20]. The research results show that Treatment with differentiated learning strategies is better based on the results of data analysis than Treatment using conventional learning strategies. In this way, differentiated learning based on students' learning styles has more exciting information and facts related to the learning material. It has the opportunity to improve learning outcomes, and students' mathematical problem-solving abilities are better than the learning outcomes of mathematical problem-solving skills with conventional learning.

In line with the theory above, differentiated learning based on learning styles allows teachers to give students the support they need, which may differ from one another in differentiated learning based on the learning style the teacher faces [21]. Students express themselves, one by one, so that they understand what is being taught. Students can study in large, small groups or independently. Instead of lumping them together in one large group in a one-size-fits-all class, differentiated learning based on learning styles is delivered in smaller learning groups, making it easier for teachers to see which students have mastered the lesson objectives and have the skills to continue learning in the future. At the same time, teachers can also see students who still need support or intervention.

It is in line with research conducted by Amalia et al. [22] regarding the application of differentiated learning based on learning styles, which shows the influence of differentiated learning based on learning styles on students' mathematical problem-solving abilities. Empirically, it is also supported by the opinion in research by Komang [23] showing that students who are taught with differentiated learning based on learning styles make students feel more comfortable during the teaching and learning process; a teacher can develop learning that suits their respective learning styles. -each student, which aims to meet the different learning needs of each student.

The findings prove differences in each strategy, approach, and learning method. These findings are in line with the findings of Febriana et al. [24] and Stavrou & Koutselini [25]. Research findings prove that the application of differentiated learning based on learning styles can help students improve and enhance their abilities in solving mathematical problems and can help students be active in teaching and learning activities because students think and use their abilities to find final results and teachers provide appropriate learning with each student's learning style.

Previous research proves that differentiated learning based on learning styles has a good impact on students' mathematical problem-solving abilities and student learning. Referring to several of these explanations, the researcher concluded that differentiated learning based on learning style has a significant influence on students' mathematical problem-solving abilities.

Improving students' mathematical problem-solving abilities has a broad and significant impact on their learning process. Strong mathematical problem-solving skills can improve students' academic achievement in mathematics subjects and other fields of study that require critical and analytical thinking. Students skilled in solving mathematical problems tend to have better critical thinking abilities. They can identify issues, analyze information, and evaluate solutions effectively. To improve students' mathematical problem-solving skills, teachers can apply learning approaches and strategies that stimulate students' critical thinking, exploration, and creativity—introducing differentiated learning based on learning styles or techniques that allow students to be actively involved in the learning process. In connection with this, problem-solving abilities in mathematics learning must be optimized by implementing appropriate and innovative learning models. One of them is by implementing differentiated learning based on learning styles [26].

5. CONCLUSION

Based on decision-making, where is the Sig value? (2-tailed) ≥ 0.05, then there is no significant difference; conversely, if the Sig. (2-tailed) < 0.05, so there is a substantial difference between the pretest and posttest data. Judging from the table above, the dependent sample t-

test shows that there is a Sig value. (2-tailed) which is 0.000. In this way, it is shown that the experimental class got a Sig value. (2-tailed) which is the same, namely <0.05. Because it is known that the Sig value. (2-tailed) this class is smaller than 0.05, so it can be concluded that there is a significant or real influence between the application of differentiated learning based on learning styles and students' mathematical problem-solving abilities.

6. SUGGESTION

Students' mathematical problem-solving abilities can be developed and trained by implementing differentiated learning based on learning styles in the mathematics learning process so that students can be more optimal in solving mathematical problem-solving abilities. So, it is highly recommended for mathematics teachers to apply this learning. In this research, differentiated learning based on learning styles has significantly improved' mathematical problem-solving abilities. Based on the research carried out above, it is hoped that future researchers can develop this research and expand the scope of research, starting from subjects and objects and exploring other models further so that the research can be used more widely.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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