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The Effect of Resilience on Students' Mathematical Logical Thinking Ability

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Abstract: The ability to think logically is one of the essential skills acquired through learning mathematics, as it facilitates students in understanding material and solving problems in a rational manner. However, students often avoid working on mathematics problems due to the belief that mathematics is inherently difficult. To address this issue, students must develop positive attitudes such as self-confidence, persistence, perseverance, and optimism—traits closely related to resilience. This study aimed to examine the influence of mathematical resilience on students' logical thinking ability in mathematics among eighth-grade students at SMP Negeri 2 Kutasari. This research employed a quantitative approach using a survey method. The population consisted of all eighth-grade students at SMP Negeri 2 Kutasari, totaling 219 students. A sample of 142 students was selected using the Slovin formula and simple random sampling technique. The research instruments included a resilience questionnaire and a logical thinking ability test. Data were analyzed using simple linear regression analysis. The results showed that mathematical resilience had a significant effect on students' mathematical logical thinking ability. The coefficient of determination was 0.058, indicating that 5.8% of the variance in logical thinking ability was explained by resilience, while the remaining 94.2% was influenced by other variables not examined in this study.

Keywords: ability mathematical logical thinking; resilience mathematics; students

A. Introduction

Education is a means or a bridge for individuals to develop their potential through the learning process (Fitri, 2021). Through a systematic and directed learning process, a person can hone various abilities such as intellectual, creative, social and emotional abilities. Education is currently an important factor for every country in advancing its development.

In every country, the quality of education remains a serious topic of discussion. Quality education is essential for national development. Education is not only an "agent of change" for the young generation as the nation's successor, but also an "agent of producer" capable of bringing about real transformational change. (Safitri et al., 2022, p. p. 7097) It is widely believed that the quality of a nation improves in line with the level of its education. The Indonesian government has undertaken a major task in reforming the quality of education across all levels (Wahyudi, 2022, p. p. 19)

Mathematics is a universal, precise, and reliable field of science. According to experts, the essence of mathematics emphasizes reasoning and abstract thinking. Russeffendi states that mathematics prioritizes reasoning activities rather than results obtained from experiments or observations. It originates from the mind and is closely related to ideas, processes, and logical considerations (Dewi & Ardiyansyah, 2022, p. p. 3) Similarly, James describes mathematics as a language that employs carefully defined terminology, clear and precise symbolic representation, and concise expressions of idea (Dewi & Ardiyansyah, 2022, p. p. 4)

Based on the statements above, it can be concluded that mathematics is a scientific discipline that systematically studies patterns of relationships, modes of thinking, art, and language; each of which is examined using logical reasoning. In the context of learning, mathematical thinking is a crucial mental process for decision-making, argumentation, and analysis across various scientific fields (Suherman, 2024, p. 35). The government has set mathematics as one of the prioritized subjects because of its strategic role in shaping students thinking power.

Mathematics is one of the subjects prioritized by the government. The National Council of Teachers of Mathematics (NCTM) is an organization of mathematics teachers in the United States that defines mathematical power as having the ability to investigate, conclude and reason, solve problems, communicate systematically and connect various ideas to other intellectual activities (Maulyda, 2020, p. Page 1) One of the skills that influences mathematics learning is the ability to think logically.

The ability to think logically is the ability to think using logic, rationality and reason (Kurnia E. Lestari & Yudhanegara, 2015, p. p. 90) . This is in line with Ministerial Regulation no. 8 of 2024 concerning content standards stipulates that mathematics subjects must be given to all levels of education, namely, from elementary school to middle school (Kemdikbudristek, 2024) . According to the Ministry of National Education, mathematics needs to be given to students to equip students with mathematical thinking skills, such as logical, critical, creative thinking and so on. (Rachmantika & Wardono, 2019) . From this it can be seen that the ability to think logically is one of the skills that must be acquired in learning mathematics, because the ability to think logically makes it easier for students to understand the material and solve problems rationally.

Aristotle argued that logic is knowledge For make correct conclusion . (Rakhmat , 2013, p. p. 27) Next the Encyclopedia Britannica says that logic is study structured systematically in a way structured with reasoning and thinking logical (Rakhmat, 2013, p. p. 34) . In terms of This is in line with Willian S. Sahakian's opinion said that logic must understood past A reasoning , reasoning said logical If use draft think in logic (Rakhmat, 2013, p. p. 34) .

It can be concluded that reasoning involves the activity of explaining why a particular result is obtained based on known assumptions. Meanwhile, logical thinking encompasses broader processes, including the use of reasoning to draw logical and meaningful conclusions, particularly in solving mathematical problems. One of the essential cognitive abilities needed in mathematics is the ability to think logically and mathematically.

According to Dina et al., there are four factors that influence the ability to think mathematically and logically: motivation, prior knowledge, learning strategies, and physical condition (Anggraini & Irawan, 2021) . Setyowati defines logical thinking as a cognitive process used to draw conclusions from experience or knowledge based on facts, using arguments to solve problems and reach a reasoned conclusion (Wijayanti & Lestariningrum, 2022, p. p. 141) .

It can be concluded that mathematical logical thinking is the ability to discover truth based on facts and draw conclusions using rules and logical reasoning. Through this ability, students can arrive at correct conclusions in a logical, rational, and coherent manner, guided by systematic and structured principles. Therefore, if students possess strong mathematical logical thinking skills, they are more likely to solve mathematical problems effectively using rational thought and to achieve satisfactory results.

When learning mathematics, educators often encounter students who experience difficulties in learning mathematics, because students assumptions about mathematics are difficult. Students who are less intelligent will have difficulty thinking and doing things related to the learning they (Surur et al., 2019, p. 165). In this case, students try to avoid studying and working on mathematics problems (Azizah & Abadi, 2022, p. p. 106) . To overcome the problems above, it is necessary to have a positive attitude that must be instilled in students, including self-confidence, persistence, perseverance and optimism. This is related to resilience.

Resilience is a person's ability to adapt and be able to achieve success in facing various challenges (Hendriana et al., 2017, p. Page 176) . The *broaden and build* theory proposed by Cohn & Fredrickson explains that emotion positive that is resilience capable expand method think someone and pushed thinking new, creative ideas, coping strategies problems and possibilities individual For build Skills social and cognitive. Resilience can strengthens mentally and emotionally someone, makes it possible they For maintain focus and concentration required For thinking logical and systematic (Monty P. Satiadarma et al., Optimizing Psychological Well-Being During the Pandemic, 2021). In this context the above theory is related to mathematical resilience. For example, when a student feels challenged but is confident in working on a difficult math problem, he will think of using an approach that has never been tried before, such as making a model or illustrating mathematics, changing perspectives, and discussing with friends. This contributes directly to the development of mathematical resilience, namely the ability to persist, bounce back, and try again despite facing difficulties in learning mathematics. Thus, positive emotional experiences encourage students to be more flexible, creative, and persistent in solving various mathematical problems.

Resilience can understood as ability individual For survive and overcome problem with adapt and explore For find solution problems faced . Resilience is very important for man For overcome all difficulty every day . In the context of education, resilience is an essential trait that students need to develop. In addition to helping them manage negative emotions and reduce stress, resilience is also closely related to the development of students' skills. These skills include both hard skills and soft skills. In classroom learning, teachers often focus primarily on developing students' hard skills, while their soft skills tend to be overlooked.

However, students can also cultivate soft skills through the learning process. One of the most important soft skills for students particularly in mathematics is mathematical resilience.

Based on description above it can concluded that mathematical resilience is attitude diligent and capable endure in finish problem mathematics. Resilience have very important role in life man. Someone who has good resilience capable utilise various existing potential in himself in a way maximum. In the learning process mathematics, students need own good resilience so that capable overcome various problem mathematics.

According to Mr. Hakim, a mathematics teacher at SMP Negeri 2 Kutasari, many eighth-grade students at the school struggle to maintain a diligent and persistent attitude when solving mathematical problems. However, there are also several students who actively engage in the learning process by asking questions or discussing problems with their peers. This indicates a desire to deepen their understanding of the material through collaborative learning.

In addition, students in class VIII demonstrate varying levels of logical thinking ability. Some are able to identify relevant information, construct logical arguments, and draw conclusions based on the problems given. However, others still experience difficulties in performing these tasks.

Based on the problems above, researchers suspect that there is a relationship between mathematical resilience and the ability to think mathematically logically. Therefore, the researchers are interested in conducting research with the title "The Effect of Mathematical Resilience on the Mathematical Logical Thinking Ability of Class VIII Students of SMP Negeri 2 Kutasari ".

B. Method

Based on the nature of the problem, the researchers employed a quantitative approach. In terms of the research method, this study falls under the category of survey research. The survey method is a technique for collecting information using a list of questions to be answered by respondents (Sugiyono, 2015) . To assess the reliability of the research instruments, a reliability test was conducted using the Cronbach's Alpha coefficient. According to (Priyastama, 2017),an instrument is considered reliable if the reliability coefficient (alpha value) is greater than 0.60.

After the data were collected, statistical testing was conducted to determine whether the results, presented in the form of quantitative scores, could be accepted or rejected. This study involved two variables: the independent variable, namely mathematical resilience, and the dependent variable, which is the students' mathematical logical thinking ability. To measure students' level of mathematical resilience, a questionnaire was used consisting of 30 items, including both positive and negative statements. Responses to these statements were rated using a Likert scale. The type of test used to assess mathematical logical thinking ability was a descriptive test consisting of five questions, each aligned with specific indicators of logical thinking in mathematics. Each response was scored on a scale with a maximum value of 4.

This technique was used to collect data on the learning outcomes of eighth-grade students related to their mathematical logical thinking abilities, using test questions based on the mathematics material for class VIII. The formula used for testing instrument reliability was Cronbach's Alpha. The study was conducted at SMP Negeri 2 Kutasari, located on Jl. Tobong, Kutasari District, Purbalingga Regency, Central Java. The researchers chose this location to investigate students' mathematical resilience and their mathematical logical thinking abilities. The study was carried out during the even semester of the 2023/2024 academic year. The population in this study consisted of all eighth-grade students at SMP Negeri 2 Kutasari in the 2023/2024 academic year, totaling 219 students. The sample for this study was selected using a probability sampling technique.

In collecting the sample, the researchers employed a simple random sampling technique. The sample size was determined using the Slovin formula with a 5% margin of error, resulting in a total sample of 142 students. After data collection, the first step was to test the validity and reliability of the research instruments. This process was carried out with the assistance of Microsoft Excel and subsequently analyzed using SPSS software. The validity of the data was tested using the Pearson Product-Moment correlation formula. The instrument trials were administered to eighth-grade students at SMP Negeri 2 Kutasari who were not part of the study sample. The data collected were analyzed through prerequisite tests, including the normality test, linearity test, and regression significance test. After these prerequisite analyses were conducted, hypothesis testing was performed to determine whether mathematical resilience had a significant influence on students' mathematical logical thinking ability. A simple linear regression test was used to test the hypothesis, while the magnitude of the influence was assessed using the coefficient of determination (R square).

C. Results and Discussion

1. Results

Data analysis techniques are methods used to manage and interpret data so that research results can be presented systematically. In this study, quantitative analysis techniques were used to determine the effect of mathematical resilience (X) on students' mathematical logical thinking skills (Y). These two variables are based on the theoretical framework that has been explained in the literature review, where mathematical resilience is considered as one of the important factors that can support the logical thinking process in solving mathematical problems. The research instrument to measure mathematical resilience consists of 30 statement items. Based on the results of the validity test using the Pearson Product Moment correlation, it is known that 22 items were declared valid, while 8 other items were invalid, namely items number 6, 8, 13, 15, 17, 25, 26, and 30. These invalid items were not used in further analysis because they did not meet the instrument's validity standards. On the other hand, all 5 questions used to measure mathematical logical thinking skills were declared valid and could be used.

Test prerequisites analysis done For ensure that all conditions used has fulfilled before carry out regression tests. As for technical Data analysis was carried out , among others as following :

a. Descriptive statistics

1) Description Resilience Mathematical

Based on questionnaire data results resilience mathematics, totaling 22 statement items spread to student class VIII of SMP Negeri 2 Kutasari as many as 142 students. Before spread to sample study Already testing was carried out validity and reliability. After that, done data analysis statistics descriptive with use application *SPSS*. Obtained data as following :

Table 1. Descriptive Resilience Statistics Output Results

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Mathematical_Resilience	142	34	76	58.28	7,390
Valid N (listwise)	142				

Table 1 shows data from 142 respondents, with an average score of 58.28, indicating that most students are at a moderate level of resilience. This suggests that, in general, students have reasonably good abilities in dealing with difficulties in learning mathematics, although there is still room for improvement.

The highest score is 76, and the lowest is 34, indicating a considerable disparity in resilience levels among students. This highlights the need for an adaptive and responsive learning approach that addresses differences in student characteristics. Some students may already possess effective strategies for overcoming mathematical challenges, while others still require guidance and support.

The standard deviation of 7.390 also indicates that the distribution of mathematical resilience scores among students is quite varied. This suggests that students possess differing levels of resilience in learning mathematics. Teachers can use this information to identify students with low resilience and provide targeted support, such as tutoring, motivational strategies, or emotion-based learning interventions. After conducting descriptive statistical calculations, the researcher categorized students' mathematical resilience into three levels, as follows:

Table 1. Mathematical Resilience Category

Category	Formula
Low	$x < \text{Mean} - \text{Standard Deviation}$ $x < 58{,}28 - 7{,}390$ $x < 50{,}89$
Currently	$\text{Mean} - \text{Standard Deviation} \leq x < \text{Mean} + \text{Standard Deviation}$ $58{,}28 - 7{,}390 \leq x < 58{,}28 + 7{,}390$ $65{,}67 \leq x < 50{,}89$
Tall	$x \geq \text{Mean} + \text{Standard Deviation}$

Category	**Formula**
	$x \geq 58{,}28 + 7{,}390$ $x \geq 65{,}67$

Based on the categories in table 2, the next step was to calculate the frequency distribution using SPSS. The resulting data are presented as follows:

Table 3. Mathematical Resilience Frequency Distribution Output

Mathematical_Resilience_Category

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	19	13.4	13.4	13.4
	Currently	102	71.8	71.8	85.2
	Tall	21	14.8	14.8	100.0
	Total	142	100.0	100.0	

Based on the frequency distribution output revealed in table 3, 21 students (14.8%) were categorized as having high mathematical resilience, 102 students (71.8%) were in the moderate category, and 19 students (13.4%) were in the low category. These results indicate that the majority of students at SMP Negeri 2 Kutasari have a moderate level of mathematical resilience.

2) Ability Mathematical Logical Thinking

The data on students' mathematical logical thinking ability were obtained from five test items administered to 142 eighth-grade students at SMP Negeri 2 Kutasari. The data were then analyzed using descriptive statistical methods with the assistance of the SPSS application. The results are presented as follows:

Table 4. Descriptive Statistical Output of Logical Thinking Ability

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Thinking_Logical	142	25	85	59.01	10,739
Valid N (listwise)	142				

Table 4 shows data from 142 respondents. The average score of students' mathematical logical thinking ability was 59.01, with the highest score being 85, the lowest score 25, and a standard deviation of 10.739. After conducting descriptive statistical calculations, the researcher categorized students' mathematical logical thinking ability into three levels, as follows:

Table 5. Categories of Mathematical Logical Thinking Ability

Category	**Formula**
Low	$x < \text{Mean} - \text{Standard Deviation}$ $x < 59{,}01 - 10{,}739$ $x < 48{,}281$ $x < 48{,}28$
Currently	$\text{Mean} - \text{Standard Deviation} \leq x < \text{Mean} + \text{Standard Deviation}$ $59{,}01 - 10{,}739 \leq x < 59{,}01 + 10{,}739$ $48{,}281 \leq x < 69{,}739$ $48{,}28 \leq x < 69{,}74$
Tall	$x \geq \text{Mean} + \text{Standard Deviation}$ $x \geq 59{,}01 + 10{,}739$ $x \geq 69{,}739$ $x \geq 69{,}74$

Based on the categories in table 5, a frequency distribution analysis was then conducted using SPSS. The results are presented as follows:

Table 6. Frequency Distribution Output of Mathematical Logical Thinking

Category_Logical_Thinking

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	21	14.7	14.8	14.8
	Currently	92	64.3	64.8	79.6
	Tall	29	20.3	20.4	100.0
	Total	142	99.3	100.0	

Based on the frequency distribution output seen in table 6, 29 students (20.3%) were categorized as having a high level of mathematical logical thinking ability, 92 students (64.3%) were in the moderate category, and 21 students (14.7%) were in the low category. These results indicate that, on average, students at SMP Negeri 2 Kutasari possess a moderate level of mathematical logical thinking ability.

b. Analysis Prerequisite Test

1) Normality test

The normality test is used to determine whether the data are normally distributed. In this study, the Kolmogorov-Smirnov test was conducted using SPSS. The decision criteria are as follows: if the Kolmogorov-Smirnov significance value (Sig.) is ≥ 0.05, the data are considered normally distributed; if the Sig. value is < 0.05, the data are not normally distributed. The output results are presented as follows:

Table 7. Normality Test

One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residuals
N		142
Normal Parameters [a, b]	Mean	.0000000
	Std. Deviation	10.42456915
Most Extreme Differences	Absolute	.073
	Positive	.073
	Negative	-.065
Statistical Tests		.073
Asymp . Sig. (2- tailed) [c]		,062

Based on the table 7, the data are considered normally distributed because the significance value is 0.062, which is greater than 0.05. Therefore, the results of the Kolmogorov-Smirnov normality test indicate that both mathematical resilience and mathematical logical thinking ability are normally distributed.

2) Linearity Test

This test was used to determine whether the independent and dependent variables have a linear relationship. The analysis was performed using SPSS by examining the "Deviation from Linearity" value. The decision criterion for the linearity test is as follows: if the significance value (Sig.) is ≥ 0.05, then the regression line is considered linear. Conversely, if the Sig. value is < 0.05, the regression line is considered not linear. The output results are presented as follows:

Table 8. Linearity Test

ANOVA Table

			Sum of Squares	Df	Mean Square	F	Sig.
Logical_Thinking * Mathematical_Resilience	Between Groups	(Combined)	5129.839	30	170,995	1,705	.024
		Linearity	939,270	1	939,270	9,366	,003
		Deviation from Linearity	4190.569	29	144,502	1,441	,091
	Within Groups		11132.133	111	100,289		
	Total		16261.972	141			

The results of the linearity test in table 8 show a significance value of 0.091, based on the "Deviation from Linearity" output. Since the significance value is 0.091, which is greater than 0.05, it can be concluded that there is a linear relationship between mathematical resilience and mathematical logical thinking ability.

3) Regression Significance Test

The regression significance test is used to determine whether the independent and dependent variables have a statistically significant regression relationship. The decision criteria for this test are as follows: (1) If the significance value (Sig.) is ≥ 0.05, then the regression is not statistically significant; (2) If the significance value (Sig.) is < 0.05, then the regression is statistically significant. The output results are presented as follows:

Table 9. Regression Significance Test

ANOVA [a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	939,270	1	939,270	8,582	.004 [b]
	Residual	15322.702	140	109,448		
	Total	16261.972	141			

Based on the results of the regression significance test, the obtained significance value is 0.004. Since this value is less than 0.05, the regression is considered statistically significant. Therefore, it can be concluded that the variable of mathematical resilience can be used to predict students' mathematical logical thinking ability.

c. Hypothesis Testing

This test was conducted to determine whether there is an influence of mathematical resilience on the mathematical logical thinking ability of eighth-grade students at SMP Negeri 2 Kutasari. The hypotheses for this study are as follows:

H_0: There is no significant effect of students' mathematical resilience on their mathematical logical thinking ability.

H_1: There is a significant effect of students' mathematical resilience on their mathematical logical thinking ability.

The criteria for hypothesis testing decisions are as follows:
If the significance value (Sig.) < 0.05, then **H_0 is rejected**. Conversely, if the significance value (Sig.) ≥ 0.05, then **H_0 is accepted**.

Before conducting the hypothesis test, several prerequisite tests were required, as described below:

1) Simple Linear Regression Analysis

This analysis was used to determine the direction of the relationship between mathematical resilience and mathematical logical thinking ability—whether the relationship shows an increase or a decrease. The analysis was conducted using SPSS, and the output results are presented as follows:

Table 10. Simple Linear Regression Test

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	38,660	7,003		5,520	,000
	Mathematical_Resilience	,349	,119	,240	2,929	,004

a. Dependent Variable: Logical_Thinking

Based on the simple linear regression output table, the value of **a** (the constant) is 38.660, and the value of **b** (the regression coefficient) is 0.349. The simple linear regression equation can be written in general form as follows:

$$\hat{Y} = a + bX$$

$$\hat{Y} = 38{,}660 + 0{,}349X$$

From the equation above, it can be seen that the regression coefficient (**b**) has a positive value. This indicates a positive relationship between mathematical resilience (X) and mathematical logical thinking ability (Y). Thus, if students' mathematical resilience increases by one unit, their mathematical logical thinking ability is expected to increase by 0.349 points.

Based on the table above, the significance value is 0.004. Since 0.004 < 0.05, the null hypothesis (**H_0**) is rejected and the alternative hypothesis (**H_1**) is accepted. It can therefore be concluded that there is a significant influence of mathematical resilience on the mathematical logical thinking ability of eighth-grade students at SMP Negeri 2 Kutasari.

2) Coefficient Determination

The coefficient of determination is obtained by squaring the correlation coefficient and multiplying it by 100 (Anwar, 2009, p. p. 87) .

It is used to determine the extent to which the independent variable influences the dependent variable, as indicated by the value of R^2. The coefficient of determination shows how much influence variable X (mathematical resilience) has on variable Y (mathematical logical thinking ability). The SPSS output for this analysis is presented as follows:

Table 11. Coefficient Test Results Determination

Model Summary [b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,240 [a]	,058	,051	10,462

a. Predictors: (Constant), Mathematical_Resilience

b. Dependent Variable: Logical_Thinking

Based on the coefficient table, the value of R Square is 0.058. This means that mathematical resilience has an influence of 5.8% on the mathematical logical thinking ability of eighth-grade students at SMP Negeri 2 Kutasari. The remaining 94.2% is influenced by other variables not examined in this study.

2. Discussion

In this discussion, the researcher will explain the results of the study that has been conducted. The research was carried out at SMP Negeri 2 Kutasari, with the subjects being eighth-grade students. The population consisted of 219 students, from which a sample of 142 students was selected using the Slovin formula. To test the reliability of the instruments used in this study, a reliability test was conducted using the Cronbach's Alpha coefficient. An alpha value greater than 0.60 was used as the threshold for determining reliability. This study aimed to determine whether there is an influence of students' mathematical resilience on their mathematical logical thinking ability. The instruments used in this study were a questionnaire and a test.

Instrument trials were conducted prior to distributing the research instruments to the study sample. These trials were carried out to determine whether the instruments were valid and reliable. The trials involved 32 eighth-grade students outside of the study sample, and both validity and reliability tests were performed using SPSS Version 27. The results showed that 22 items in the mathematical resilience questionnaire were declared valid, and 5 items from the mathematical logical thinking ability test were also declared valid. Based on the reliability test, the mathematical resilience questionnaire was found to be reliable, with a Cronbach's Alpha value of 0.849 (> 0.60). Therefore, the instrument was deemed reliable. Similarly, the reliability test for the mathematical logical thinking ability test yielded an Alpha value of 0.666 (> 0.60), indicating that this instrument was also reliable. As a result, since both instruments were valid and reliable, they were deemed suitable for distribution to the research sample.

Before conducting the prerequisite tests, a descriptive statistical analysis was first carried out on the questionnaire and test instruments. For the questionnaire instrument, the average score of eighth-grade students at SMP Negeri 2 Kutasari was 58.28, with the highest score being 76, the lowest score 34, and a standard deviation of 7.390. Meanwhile, for the test instrument, the average score was 59.01, with the highest score being 85, the lowest score 25, and a standard deviation of 10.739. Based on the average scores obtained from the mathematical resilience questionnaire and the mathematical logical thinking ability test, the data were categorized into three levels: low, moderate, and high.

Based on the data processed using SPSS Version 27, it was found that the majority of students at SMP Negeri 2 Kutasari had a **moderate level of mathematical resilience**, with a percentage of 71.8%. Similarly, the average mathematical logical thinking ability of students at the same school was also categorized as **moderate**, with a percentage of 64.3%. Furthermore, prerequisite tests were conducted prior to hypothesis testing. These included the **normality test**, **linearity test**, and **regression significance test**.

The results of the normality test showed that the data on mathematical resilience and mathematical logical thinking ability were normally distributed, with a significance value of 0.062, which is greater than 0.05 (0.062 > 0.05). The linearity test showed that the relationship between mathematical resilience and mathematical logical thinking ability was linear, with a significance value of 0.091 (0.091 > 0.05). The regression significance test indicated that the relationship between mathematical resilience and mathematical logical thinking ability was statistically significant, with a significance value of 0.004 (0.004 < 0.05). Therefore, the regression model is considered significant. After these prerequisite tests were conducted, hypothesis testing was carried out using a simple linear regression analysis to determine whether mathematical resilience influences mathematical logical thinking ability. To measure the strength of this influence, the coefficient of determination (R Square) was examined.

In the simple linear regression test, the obtained significance value was 0.004. Since 0.004 < 0.05, the null hypothesis (**H_0**) is rejected and the alternative hypothesis (**H_1**) is accepted. This indicates that there is a significant influence of mathematical resilience on the mathematical logical thinking ability of eighth-grade students at SMP Negeri 2 Kutasari.

The regression equation derived from this study is:

$\hat{Y} = 38{,}660 + 0{,}349X$. These results show that the **b** coefficient is positive, which means that as the value of the **X** variable (mathematical resilience) increases, the **Y** variable (mathematical logical thinking ability) also increases. Specifically, if mathematical resilience increases by one unit, the logical thinking ability is expected to increase by 0.349 units.

It can be concluded that if students increase their mathematical resilience, their ability to think logically in mathematics will also improve. Students who demonstrate a high level of perseverance are more likely to persist and not easily give up when faced with challenging mathematical problems. One way to improve students' mathematical resilience is through peer discussions. Discussion is one of the key indicators of mathematical resilience. Collaborating with peers, by sharing ideas and helping each other, makes it easier for students to understand and solve mathematical problems. Another strategy is encouraging students to regularly practice solving problems they previously could not answer and to utilize various learning media to deepen their understanding of the material. This is important because not all students are able to fully grasp the material explained by the teacher. By doing so, students' mathematical logical thinking ability can continue to be sharpened and developed effectively.

The coefficient of determination (R Square) indicates that the influence of mathematical resilience on mathematical logical thinking ability is 0.058, or 5.8%. The remaining 94.2% is influenced by other variables not examined in this study. This finding is supported by previous research conducted by Yunia Tri Widya Rahayu, Khoirul Qudsiyah, and Dwi Cahyani Nur Apriyani, which found a significant relationship between mathematical resilience and the logical thinking ability of high-achieving eighth-grade students at SMP Negeri 1 Pacitan. (Wati et al., 2020) .

This finding is in accordance with the theory that states mathematical resilience needs to be continuously developed and improved. Furthermore, this study is also in line with the research conducted by Syifa Syafira Al Ghifaria and Dian Usdiyana, whose results concluded that there is a significant positive relationship between mathematical resilience and problem-solving ability. Students with high mathematical resilience tend to find it easier to complete problem-solving tasks effectively compared to students with low mathematical resilience. (Ghifari & Usdiyana, 2023, p. p. 534) .

In teaching and learning activities, teachers should not only aim to improve students' academic scores but also pay attention to aspects that increase students' interest in learning. One important factor in enhancing students' cognitive abilities is fostering self-resilience. By developing students' resilience, teachers can more effectively achieve learning objectives. (Suparni et al., 2021, p. Page 164) .

D. Conclusion

Based on the research conducted, it can be concluded that there is a significant influence of students' mathematical resilience on their mathematical logical thinking ability among eighth-grade students at SMP Negeri 2 Kutasari. The magnitude of this influence is 5.8%, while the remaining 94.2% is influenced by other variables that were not examined in this study. Therefore, it can be concluded that the higher a student's mathematical resilience, the higher their ability to think logically in mathematics. Conversely, students with low mathematical resilience tend to have lower logical thinking ability in mathematics.

The implications of this study suggest that strengthening mathematical resilience is an important aspect of mathematics education in schools. Mathematics teachers need to design learning strategies that not only focus on cognitive development but also cultivate students' mental toughness and positive attitudes toward mathematical challenges. This can be achieved through approaches such as problem-based learning, emotional reflection, and classroom-based social support. In this way, mathematics learning can serve as a platform not only for developing logical thinking skills but also for building students' resilience and character.

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The Effect of Applying the Peer Tutoring Model on Fifth-Grade Students' Ability to Solve Mathematical Word Problems

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Abstract: Mathematics is one of the sciences that plays an important role in human life. Through learning mathematics, students are trained to think critically, logically, and systematically, as well as to solve the problems they encounter in daily life—many of which are presented in the form of mathematical word problems. Based on initial observations, students' ability to solve mathematical word problems is still relatively low. Therefore, efforts are needed to improve this ability, one of which is through the implementation of the peer tutoring learning model. This research used a quasi-experimental method with a pretest–posttest control group design. The population in this study consisted of fifth-grade students from public elementary schools in the Darussalam sub-district. The sample included 25 students from Ujong Kuta Public Elementary School and 7 students from Tanjung Selamat Public Elementary School. Data were collected using a mathematical word problem-solving ability test. Data analysis was conducted using the Independent Samples t-test via the SPSS application. Based on the analysis of the posttest scores, the Sig. (2-tailed) value was 0.003, which is less than 0.05. These results indicate that the peer tutoring model had a significant effect on the ability of fifth-grade students to solve mathematical word problems.

Keywords: peer tutor; ability; questions story

A. Introduction

Raharjo, in the journal *The Great*, states:

> *"Mathematical word problems are questions that contain and reflect real-life situations, which can be solved using mathematical language."*

The term *mathematical language* here refers to supporting sentences that contain mathematical understanding—such as numbers, arithmetic operations, and relationships. However, the ability of fifth-grade students to solve mathematical word problems is still considered low. This is supported by empirical data, where the average score of Grade V students was 29.76, with the following percentage of achievement across five indicators: 19% on the ability to read the question, 7% on the ability to understand the question, 11% on the ability to transform the problem, 8% on process skills, and 3% on the ability to present the answer. Based on the test results, the researcher concluded that out of the five indicators, only one met the minimum standard.

The ability to solve mathematical word problems refers to the skills involved in analyzing, solving, and answering questions in accordance with learning objectives and the intended meaning of the problem. Word problem solving is a crucial aspect of mathematics, as it involves real-life application and requires students to interpret and process information presented in textual form.

According to Newman's procedure, the steps for solving mathematical word problems include: Reading – accurately reading the problem, Comprehension – understanding what the problem is asking, Transformation – translating the problem into a mathematical form, Process Skills – performing the necessary calculations, Encoding – writing the correct answer in the required format (Afwika, Aprilia, et al., 2023).

According to Haryati,

> *"The competencies that students must possess in solving mathematical word problems include meaningful verbal ability, the ability to understand and interpret questions, and the ability to translate them into mathematical models. In addition, algorithmic ability is also essential—that is, the student's ability to determine the correct algorithm to solve the problem, perform accurate calculations, and draw appropriate conclusions from the results, which should be connected back to the original question." (Afwika, Aprilia, et al., 2023)*

Peer tutoring is a learning strategy in which students are appointed or assigned to assist their classmates who are experiencing learning difficulties. This approach is effective because relationships among peers are generally closer and more relaxed than the relationships between teachers and students. In peer tutoring, both the tutor and the tutee are students of the same age or academic level. The tutor acts as a teacher, while the tutee is the learner, both being peers. Peer tutoring is essentially similar to mentoring programs that aim to provide support by students and for students, enabling them to achieve optimal learning outcomes (Abdul Mukhlis, 2016).

Before selecting a tutor, the teacher must consider several factors to ensure that the intended learning objectives can be achieved. According to Anggorowati, a peer tutor should meet the following criteria: (1) Possess academic abilities that are above the class average; (2) Be able to work collaboratively with fellow students; (3) Have high motivation to achieve strong academic performance; (4) Demonstrate tolerance and consideration toward peers; (5) Be highly motivated to make the discussion group successful; (6) Exhibit humility, courage, and a strong sense of responsibility; and (7) Enjoy helping others who are experiencing learning difficulties (Mutma'inah, 2022).

B. Method

This study is an experimental research using a quantitative approach. Experimental research is a method used to determine the effect of an independent variable (treatment) on a dependent variable (outcome) under controlled conditions (Sugiyono, 2020).

This study applied a quasi-experimental design in the form of a nonequivalent control group design. A quasi-experiment is a type of pseudo-experimental design in which a control group exists, but not all external variables can be controlled during implementation.

The first step involved administering a pre-test to both the experimental class and the control class. Then, the experimental class received treatment in the form of the peer tutoring model, while the control class received conventional learning. After the treatment, a post-test was administered to both classes to determine the difference in students' problem-solving abilities after receiving different treatments.

This research was conducted from October 7 to October 22, 2024. The population of the study consisted of all fifth-grade students in public elementary schools in the Darussalam sub-district. The sample included 25 students from SDN Ujong Kuta (experimental class) and 7 students from SDN Tanjung Selamat (control class). The sampling method used was simple random sampling, which is a technique of selecting sample members randomly without considering strata within the population (Sugiyono, 2020).

The data used in this study were obtained from tests. The instrument was in the form of a mathematical word problem-solving test, designed to measure students' ability to solve story problems. The test was constructed based on problem-solving indicators and was administered before learning (pre-test) and after learning (post-test).

The collected data were then analyzed to determine whether there was an influence of the peer tutoring model on students' mathematical word problem-solving ability. Data analysis included prerequisite tests and a t-test. The prerequisite tests included a normality test and a homogeneity test, analyzed using SPSS version 26.

The Shapiro–Wilk test was used for the normality test, as it is suitable for sample sizes less than 50 ($n < 50$). The decision criteria were: if the significance value is greater than 0.05, the data are normally distributed; otherwise, they are not.

The homogeneity test was also conducted, with the decision criterion being: if the significance value is greater than 0.05, the data have homogeneous variance; otherwise, the variance is not homogeneous.

Once the data met the assumptions of normality and homogeneity, a t-test was conducted. The decision criteria for the t-test are:

a. If the significance value (2-tailed) > 0.05, then H_0 is accepted and H_a is rejected.

b. If the significance value (2-tailed) ≤ 0.05, then H_0 is rejected and H_a is accepted.

The hypotheses of this study are as follows:

a. H_0: $\mu_1 = \mu_2$ The peer tutoring model has no significant effect on the ability to solve mathematical word problems in Grade V students.

b. H_a: $\mu_1 > \mu_2$ The peer tutoring model has a significant effect on the ability to solve mathematical word problems in Grade V students.

C. Results and Discussion

1. Description Peer Tutor Model Implementation Data Analysis

The researchers implemented the peer tutoring model in the experimental class. Data were obtained from student test activities, where the test questions were designed to reflect the assessment indicators used as the basis for evaluating students' mathematical word problem-solving abilities.

Table 1 presents the indicators and scoring guidelines used for the evaluation.

Table 1. Indicators Evaluation Ability Solving Math Story Problems

No	Indicator	Information	Mark
1	Understanding	- Writes both the known and the asked information correctly	4
		- Writes either the known or the asked information correctly	3
		- Writes both the known and the asked information, but inaccurately	2
		- Does not write the known and the asked information	1
2	Problem Transformation	- Develops a complete and accurate plan to solve the problem	4
		- Develops a partial plan that still leads to the correct answer	3
		- Develops a plan that leads to an incorrect answer	2
		- Does not develop a problem-solving plan	1
3	Process Skills	- Solves the problem systematically with a correct result	4
		- Solves the problem systematically, but with an incorrect result	3
		- Solves the problem unsystematically but gets a correct result	2
		- Solves the problem unsystematically and gets an incorrect result	1
4	Final Answer & Conclusion	- Writes the final answer and conclusion correctly and completely	4
		- Writes the final answer and conclusion correctly, but not completely	3
		- Writes the final answer and conclusion incorrectly	2
		- Does not write the final answer or conclusion	1

Source: Adapted from Aprilia Afwika, Nida Jarmita, and Zikra Hayati (Journal)

2. Peer Tutor Model Implementation Data Analysis

a. Class Pre-test and Post-test Data Experiment

Table 2. Class Pre-test and Post-test Conversion Scores Experiment

Student Code	Pre-test score (conversion)	Post-test score (conversion)
NU	45,815	62,086
NM	41,072	59,524
NA	25,956	42,163
SK	39,910	62,086
MF	38,389	40,158
BK	33,199	48,571
KS	33,199	46,092
RF	20,000	31,776
NY	38,495	62,086
RG	33,199	45,519
M N	20,000	42,415
A.F.	22,314	49,271
GB	40,202	62,086
FQ	36,818	55,091
HA	20,000	35,554
FR	42,084	62,086
SM	35,364	54,817
AH	33,199	53,858
M	36,450	50,862
MY	27,889	53,131
US	27,114	47,588
MI	33,199	41,116
DA	46,759	62,086
FI	20,000	38,580
MF	20,000	40,552

Source Data: Research Results

b. Class Pre-test and Post-test Data Control

Table 3. Class Pre-test and Post-test Conversion Scores Control

Student Code	Pre-test Score (conversion)	Post-test score (conversion)
NM	34,110	29,989
A.F.	33,557	35,180
AG	28,768	28,207
DH	36,589	36,196
KS	45,224	54,300
ML	44,737	44,535
NH	28,768	29,989

Source Data: Research Results

c. Data analysis

Based on the data obtained in this study, the next step was to analyze the data using prerequisite tests and a t-test.

1) Normality Test

Normality Test Results

		Shapiro Wilk		
	class	Statistics	df	Sig.
The ability to solve mathematical word problems	class pre-test experiment	.922	25	.058
	post- class test experiment	.928	25	.078
	class pre-test control	.873	7	.198
	post-test class control	.866	7	.173

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Based on Tables 2, 3, and 4, it can be seen that the pre-test and post-test data on students' ability to solve mathematical word problems in both the experimental and control classes are normally distributed, as the significance values are greater than 0.05. Therefore, it can be concluded that the data in this study are normally distributed.

2) Pre-test Homogeneity Test

Table 5. Results of the Pre-test Homogeneity Test

Test of Homogeneity of Variance					
		Levene Statistics	df1	df2	Sig.
The ability to solve mathematical word problems	Based on Mean	.876	1	30	. 357
	Based on Median	.751	1	30	.393
	Based on Median and with adjusted df	.751	1	29,827	.393
	Based on trimmed mean	.933	1	30	.342

Based on Table 5, it can be seen that the significance value (Sig.) is 0.357. Since 0.357 > 0.05, it can be concluded that the pre-test data from the experimental and control classes come from populations with equal variances (homogeneous).

3) Post-test Homogeneity Test

Table 6. Results of the Post-test Homogeneity Test

Test of Homogeneity of Variance					
		Levene Statistics	df1	df2	Sig.
The ability to solve mathematical word problems	Based on Mean	.175	1	30	.679
	Based on Median	.344	1	30	.562
	Based on Median and with adjusted df	.344	1	28.108	.562
	Based on trimmed mean	.266	1	30	.610

Based on Table 6, it can be seen that the significance value (Sig.) is 0.679. Since 0.679 > 0.05, it can be concluded that the post-test data from the experimental and control classes come from populations with equal variances (homogeneous).

4) t-test

Table 7. Results of the Independent Sample t-test on the class post-test data experiments and classes control

Independent Samples Test										
		Levene's Test for Equality of Variances		t-te st for Equality of Means						
									% Confidence Interval of Diffe rence	
		F	Sig.	t	df	Sig. (2-taile d)	Me an Diffe rence	Std. E rror Diffe rence	Lowe r	Uppe r
The ability to solve mathematical word problems	Equal variances assumed	.175	.679	3.232	30	**.003**	13.052446	4.038838	4.804037	21.300854
	Equal variances assumed			3.231	9,638	.009	13.052446	4.039807	4.005190	22.099701

Source Data : SPSS For Windows 26

Based on Table 7, it can be seen that the significance value (2-tailed) is 0.003. Since 0.003 < 0.05, it can be concluded that H_a is accepted and H_0 is rejected. This means that the peer tutoring model has a significant effect on the ability of Grade V students to solve mathematical word problems.

D. Conclusion

The implementation of the peer tutoring model by the researcher for the Grade V students at Ujong Kuta Elementary School was carried out effectively. This is supported by the results of the study, which examined the effect of implementing the peer tutoring model on students' ability to solve mathematical word problems. The following conclusion was obtained: Based on the results of the hypothesis test, the significance value (2-tailed) was 0.003. Since 0.003 < 0.05, it can be concluded that H_a is accepted and H_0 is rejected. This means that the peer tutoring model has a significant influence on the mathematical word problem-solving ability of Grade V students.

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Exploration Of Ethnomathematics In Traditional Tea Processing In Banyumas As A Source of Mathematics Learning

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Abstract: This study explored ethnomathematics within the traditional tea processing in Banyumas Regency, aiming to examine its potential as a source for mathematics learning and its integration into instructional design. A qualitative ethnographic approach was employed at two sites: a home industry in Menggala Village, which processes raw tea leaves into semi-finished product, and another in Pasiraman Kidul Village, which refines semi-finished tea into consumable tea. Data were collected through interviews, observations, and documentation. Interviews were conducted with home industry owners to understand their techniques and knowledge related to mathematical concepts. Observations focused on daily activities, tools, and processes used in tea production. Findings revealed the presence of mathematical concepts such as geometry, measurement, ratios, decay, and set theory across various stages of tea production. Ethnomathematical activities identified included measuring ingredients, designing tools, counting quantities, determining optimal locations, and explaining procedures, which highlighted the relevance of traditional knowledge in mathematics education.

Keywords: ethnomathematics; traditional tea processing; mathematics learning resource

A. Introduction

Mathematics is a structured field of study that examines patterns of thought, relationships, language, and even art in a logical manner (Khaesarani & Khairani Hasibuan, 2021). Generally, mathematics involves the study of numbers and all aspects related to calculations, including methods for solving problems concerning measurement, shapes, and changes in numerical and geometric contexts. In education, mathematics is considered a fundamental discipline, as it is consistently included in curricula across all educational levels (Damayanti et al., 2021).

Although mathematics is introduced early in education, Indonesian students' performance in the 2018 PISA assessment for mathematical literacy remained below expectations, showing a declining trend compared to previous years. In the overall PISA (*Programme for International Student Assessment*) rankings for 2018, Indonesia was placed 72nd out of 77 participating countries, with an OECD (*Organization for Economic Cooperation and Development*) score of 379—significantly lower than the average score of

487 (Putrawangsa & Hasanah, 2022). This poor performance has been attributed to the perception of mathematics as intimidating, causing many students to experience anxiety and stress when confronted with mathematical problems (Khaesarani & Khairani Hasibuan, 2021). The abstract nature of mathematical concepts often makes them difficult for students to comprehend (Kholisa, 2021).

Mathematical literacy refers to the ability to solve problems by applying logical reasoning and critical thinking skills. It is defined as the capacity to understand various contexts, solve problems effectively, and communicate solutions to others using mathematical methods (Hayati & Jannah, 2024).

Literacy plays a crucial role in students' academic and personal development, serving as a key to acquiring knowledge, understanding information, and enhancing critical thinking skills. The ability to read, write, and interpret information equips students with essential competencies for success in both education and daily life. Similarly, mathematical literacy is vital, as it enables students to formulate, apply, and interpret mathematical concepts effectively in real-world problem-solving scenarios (Hayati & Jannah, 2024).

One approach to enhancing mathematical literacy is through innovative teaching methods, such as integrating ethnomathematics into mathematics education. Ethnomathematics-based instruction is considered a meaningful and contextualized approach, as it connects mathematical learning to cultural practices and community traditions. This approach offers an engaging, enjoyable, and innovative alternative, allowing students to understand mathematical concepts within a cultural context based on their experiences as members of a society. As a result, culturally relevant mathematics education is expected to contribute to the broader literacy movement (Fajriyah, 2018).

Ethnomathematics supports mathematical literacy by enabling students to construct mathematical concepts as part of their literacy skills, drawing upon their knowledge of social and cultural environments. Additionally, ethnomathematics fosters a more engaging and motivating learning atmosphere, thereby increasing students' interest in mathematics. Consequently, this approach has the potential to enhance students' mathematical abilities, particularly in terms of mathematical literacy (Fajriyah, 2018).

Indonesia, as a diverse nation, is characterized by a rich cultural heritage encompassing various ethnicities, languages, religions, and traditions. Indonesia's cultural diversity is evident in traditional houses, ceremonies, food, and crafts dances, attire, cuisine, and other regional customs (Fitri Lintang & Ulfatun Najicha, 2022). One region known for its rich cultural heritage is Banyumas.

Banyumas, located in Central Java Province, is situated between 7°15' and 7°37' South Latitude and 108°39' and 109°27' East Longitude. Geographically, it shares borders with Purbalingga, Banjarnegara, and Kebumen Regencies to the east; Brebes Regency to the west; Cilacap Regency to the south; and Tegal and Pemalang Regencies to the north. The regency comprises 27 districts, covering a total area of approximately 1,327.59 km², which accounts for around 4.04% of Central Java's total land area ((BPS), 2024).

Banyumas is renowned for its rich cultural heritage (Kumala, 2022), encompassing both natural and traditional elements that have been preserved across generations, including handicrafts, traditional foods and beverages, regional music and dances, traditional attire, ceremonies, and historical sites.

Traditional beverages serve as an integral part of a community's cultural identity, often being easily recognizable and widely consumed (Lailam & Murti, 2019). One of the most popular beverages in Indonesia, and even globally, is tea—a traditional drink known for its numerous health benefits (Fauzia et al., 2018). Tea is derived from tea leaves and is often processed using traditional methods to maintain its quality (Ekawati & Rahayu, 2021).

In Banyumas, the tea production process involves two main stages: processing raw tea leaves into semi-finished tea and refining the semi-finished product into ready-to-consume tea. Each stage requires precise management and calculation to optimize production outcomes, demonstrating the crucial role of mathematics in decision-making within tea processing.

The first stage consists of three primary processes: withering, rolling, and drying. Each of these steps relies on mathematical principles to ensure efficiency and quality. For example, during the withering process, measurements of tea leaf weight and the volume of processing equipment involve geometric and weight-related calculations. In the rolling process, weight and time measurements are used to determine the required quantity of tea leaves and the optimal duration for processing. Additionally, the drying process necessitates calculations of time and material proportions, such as the use of firewood, all of which depend on mathematical reasoning.

The second stage involves further refinement through two different processing methods original tea processing and jasmine tea processing. Traditional tools such as *jobong* and *tampir* are used in this phase, each designed with specific geometric shapes to ensure uniformity and maintain quality standards. In jasmine tea processing, the use of a circular *tampir* is crucial for evenly distributing the floral aroma throughout the tea.

The jasmine tea brewing process requires precise calculations of time and temperature, even though it is carried out manually using traditional techniques. Mathematical concepts such as decay rates and ratio calculations are applied to measure the absorption of jasmine fragrance into the tea and determine the appropriate proportions of ingredients. During the humidification phase, jasmine buds are placed atop mature tea leaves in a *tampir*, creating an interaction that can be mathematically analyzed as the combination of two distinct sets the set of jasmine flowers and the set of tea leaves.

Although the tea processing method appears simple, it actually incorporates numerous mathematical elements that can be explored further. Concepts such as ratios, geometry, decay rates, set theory, and measurements of time and material quantities are not only relevant to modern industries but also play a fundamental role in long-established traditional practices.

Mathematics plays a crucial role in various aspects of life, including traditional tea production. By applying mathematical concepts such as measurement and calculation, both quality and efficiency in production can be maintained. This highlights the relevance of mathematics beyond academic settings, demonstrating its practical applications in everyday life and cultural traditions. Due to its significance, mathematics is a mandatory subject in educational curricula from early childhood to higher education (Kiranasari, 2023).

As a core subject in schools, mathematics contributes to achieving national educational goals by fostering an intelligent, creative, productive, and innovative generation in Indonesia. Students require a strong mathematical foundation to meet practical needs, solve problems, and understand various fields of study, including physics, chemistry, architecture, pharmacy, geography, and economics. Although its significance is often overlooked, mathematics is an essential component of daily activities, even in simple arithmetic operations (Kiranasari, 2023)

B. Methods

This study employed a qualitative approach, utilizing ethnographic methods. Data were collected through observations, interviews, and documentation. In simple terms, qualitative research can be understood as a type of research in which findings are not obtained through statistical methods but rather emphasize how researchers explore and understand the context and meaning of the data collected (Fiantika, 2022).

According to John W. Creswell, "A qualitative approach is one in which the inquirer often makes knowledge claims based primarily on constructivist perspectives (i.e., the multiple meanings of individual experiences, meanings socially and historically constructed, with an intent of developing a theory or pattern) or advocacy/participatory perspectives (i.e., political, issue-oriented, collaborative, or change-oriented) or both."(Creswell, 2012) This implies that, from a positivist perspective, a qualitative approach can be used to construct knowledge statements. The qualitative approach employs research methods that focus on the meanings derived from individual experiences, cultural norms, and historical contexts to develop theories or patterns of knowledge. Additionally, this method may be based on a participatory perspective, requiring engagement in political views, issues, collaboration, change, or a combination of these elements (Fiantika, 2022).

Given the research problem, this study adopts an ethnographic approach, which is a cultural approach aimed at describing and analyzing ethnomathematical concepts embedded in the traditional tea processing practices in Banyumas as a mathematical learning resource and its implementation in mathematics education. The researcher conducted fieldwork by directly engaging with the research site. The survey used in this study was descriptive, as the data would be presented in narrative or textual form rather than numerical representation.

The primary data sources in this study are the owners and workers of traditional tea processing home industries. Meanwhile, secondary data consist of information obtained indirectly by the researcher. In this study, the secondary data sources include articles, books, and journals. The research specifically focuses on ethnomathematical aspects within the traditional tea processing methods in Banyumas. After the researcher collects various data starting from observations, interviews, and documentation, the researcher analyzed the development of temporary data while in the field. Data analysis followed the stages of reduction, display, and conclusion drawing.

C. Results and Discussion

1. Analysis of Mathematical Activities in Traditional Tea Processing

Based on the introduction of traditional tea processing by collecting data through interviews and observations, researchers found mathematical activities in traditional tea processing activities. The data analysis is presented in Table 1.

Table 1. Analysis of Mathematical Activities in Traditional Tea Processing

Traditional Tea Processing Activities	Math Activities
Observe the stages of the traditional tea-making process in Banyumas.	Counting, Measuring, Explaining
Observe the traditional tea-making tools in Banyumas.	Designing
Observe the traditional tea-making place in Banyumas.	Locating
Observe the distribution activities of traditional tea production in Banyumas.	Playing

As shown in Table 1, mathematical activities were identified throughout the tea production stages.. Measurement activities are an integral part of various stages in the traditional tea-making process in Banyumas. These activities reflect the application of mathematical concepts in the daily practices of tea makers. In the withering and drying stages, weight measurement is used to determine the maximum capacity of the song, which is 15 kg of tea leaves per process. Additionally, the weight of the firewood used is also measured, with a requirement of approximately 9 kg for every 15 kg of tea leaves. The rolling process also involves weight measurement, where tea leaves are weighed up to 70 kg to match the grinding machine's capacity in a single process. Weight and time measurement are crucial in the tea cooking process. Every 2 kg of tea leaves cooked for original tea requires 12 minutes, with the leaves being turned every 4 minutes. For jasmine tea, the first cooking process takes 15 minutes with turning every 5 minutes, while the second cooking process requires 10 minutes with turning every 3 minutes. The humidification process in jasmine tea production also involves precise measurement. Every 3 kg of original tea processed into jasmine tea requires an additional 1.5 kg of jasmine flowers, ensuring a consistent ratio between tea and jasmine. During the cooling stage, weight measurement is conducted to ensure the proper capacity of the tampir, where each tampir can hold up to 3 kg of tea leaves. This ensures even cooling and prevents exceeding the recommended capacity. Meanwhile, in the packaging stage, weight measurement remains a key focus. For original tea, every 1 ounce of tea produces eight 500-size packages or four 1000-size packages. For jasmine tea, every 1 ounce yields fourteen 500-size packages or seven 1000-size packages.

Designing Activities can be found in the design of tools used in the tea-making process. For instance, the *song* is designed with a length of 3.5 meters and a diameter of 50 cm to optimize the processing capacity of up to 15 kg of tea leaves per cycle. Additionally, the *jobong* is designed to create a container capable of holding up to 2 kg of tea per batch. It has a circular surface with a diameter of 65 cm. *Tampir* is another example of a designing activity in this research. It is designed in a circular shape with a diameter of 82 cm, used in the tea moisturizing and cooling processes. Similarly, the *tungku* is designed with a circular surface and a diameter of 40 cm. Calculating Activities are found in various stages of traditional tea processing in Banyumas. In the withering and drying process, 9 kg of firewood is required for every 15 kg of tea leaves placed in the song. For the cooking process, 30 kg of semi-processed tea requires 5 kg of charcoal for original tea and 6 kg of charcoal for jasmine tea. In the moisturizing process, every 3 kg of original tea requires 1.5 kg of jasmine flowers. In the packaging stage, calculation plays a crucial role in production. For original tea, each 1-ounce portion produces eight 500-gram packages or four 1,000-gram packages. Meanwhile, for jasmine tea, 1 ounce produces 14 packages of 500 grams or seven packages of 1,000 grams. In processing fresh tea leaves into semi-processed tea, every 100 kg of fresh tea leaves yields 30 kg of semi-processed tea. Similarly, in processing semi-processed tea into ready-to-sell tea, every 30 kg of jasmine tea results in 26 kg of finished tea. Location Determination Activities relate to the locations of tea processing. The process of converting fresh tea leaves into semi-processed tea is centered in Menggala Village, located at the foot of Mount Slamet. Meanwhile, the process of converting semi-processed tea into ready-to-consume tea takes place in Pasiraman Kidul Village. Playing Activities can be identified in the distribution of tea production results to various locations, such as small shops and home industries across Banyumas and parts of Brebes. Explaining Activities are evident when describing the amount of charcoal required to ensure optimal tea processing. For example, every 30 kg of tea requires 5 kg of charcoal for original tea and 6 kg for jasmine tea. Furthermore, explaining is also essential in the packaging process, both for original and jasmine tea. These explanations focus on the number of packages produced from each carefully measured portion. For instance, every eight packages of 500 grams of original tea amount to a total weight of 1 ounce, while for jasmine tea, every seven packages result in the same total weight. Additionally, explanations are provided during the process of converting fresh tea leaves into semi-processed tea. These explanations highlight the use of firewood in drying and cooking processes. For example, for every 15 kg of tea leaves to be withered, 9 kg of firewood is required to ensure an effective process.

2. Analysis of Mathematical Concept in Traditional Tea Processing

Based on the introduction of tea in Banyumas, it is evident that tea processing in this region involves various mathematical concepts. These include geometry, measurement, ratio, decay, and set theory. The mathematical concepts found in traditional tea processing are structured based on groups of data formulated from research findings obtained in the field, which can be observed in Table 2.

Table 2. Analysis of Mathematical Concept in Traditional Tea Processing

Traditional Tea Processing	Math Concepts
The surface of jobong, partitions within jobong, tampir surface, surface of original tea (500 and 1000), surface of jasmine tea (500 and 1000), packaging stamp, surface of cooking stove, song, and song stove.	Geometry
	Measurement

Traditional Tea Processing	Math Concepts
Withering process, rolling process, drying process, cooking process, cooling process, moisturizing process, and packaging process	Proportion
Processing tea leaves into semi-processed tea, withering process, drying process, moisturizing process, packaging process, and processing semi-processed tea into ready-to-consume tea.	Decay
Processing tea leaves into semi-processed tea and processing semi-processed tea into ready-to-consume tea.	Set Theory
The moisturizing process.	

Data analysis was carried out based on the documentation, interviews, and observation that researches obtained while conducting research in the field. The result data analysis regarding mathematical concepts in traditional tea processing will be explained by researches as follows:

a. Geometry

Figure 1 The surface of Jobong

At Figure 1, *Jobong* is a tool used to process semi-processed tea into ready-to-consume tea. It is made of woven bamboo with a circular surface. The circular surface of the *jobong* has a diameter of 65 cm. In a single cooking process, the *jobong* can hold up to 2 kg of tea leaves.

Figure 2 Partitions within jobong

From the Figure 2, the partition inside the *jobong* acts as a divider, connecting the charcoal in the cooking stove to the tea leaves. It also serves as a place to hold the tea leaves during the cooking process. The partition in the *jobong* is circular, which helps distribute heat evenly. The circular partition has a diameter of 63 cm.

Figure 3 Tampir surface

At Figure 3*, Tampir* is a circular container made of woven bamboo. This container plays an important role in the production of jasmine tea, particularly in the humidification stage. The circular shape of the *tampir* is designed to facilitate coverage during humidification, ensuring optimal moisture retention. Additionally, the tampir is also used during the cooling process of jasmine tea. The *tampir* has a diameter of 82 cm, meaning its radius is half of that measurement.

Figure 4 Surface of original tea 500-an

In the packaging process of original tea, the product is divided into two types of packaging: 500-sized tea packages and 1000-sized tea packages that is shown at Figure 4. For the 500-sized tea package, a quarter-sized plastic is used, but the tea is only filled up to 1/3 of the plastic's capacity. The package is then tied in a way that forms a trapezoid, creating an attractive appearance that draws buyers' attention. The surface dimensions of the 500-an original tea package have a base length of 8.5 cm, a top length of 6 cm, and a height of 6.5 cm.

Figure 5 Surface of original tea 1000-an

For the 1000-sized tea package, a quarter-sized plastic is used. The plastic is filled with tea up to 2/3 of its capacity, then sealed using staples. This package is shaped like a triangle, giving it a neat and appealing look to attract buyers. At Figure 5, the surface of the 1000-an original tea package has a base of 6 cm and a height of 10 cm, forming an isosceles triangle with two equal sides measuring 12 cm.

Figure 6 Surface of Jasmine tea 500-an

In the packaging process of jasmine tea at Figure 6, the product is also divided into two types of packaging: 500-sized tea packages and 1000-sized tea packages. For the 500-sized jasmine tea package, a 1-ounce plastic bag is used and filled completely with tea. The plastic is then sealed with staples and shaped into a rectangle. This neat and attractive packaging is designed to capture buyers' interest and enhance the product's market appeal. The surface dimensions of the 500-sized jasmine tea package are 4.5 cm in width and 7.5 cm in length, forming a rectangular shape.

Figure 7 Surface of jasmine tea 1000-an

For the 1000-sized jasmine tea package, a quarter-sized plastic bag is used at Figure 7, filled up to 1/3 of its capacity with tea. The plastic is then sealed with staples and shaped into a rectangle. This well-organized packaging aims to attract buyers. The surface dimensions of the 1000-sized jasmine tea package are 9 cm in length and 8 cm in width, forming a rectangular shape.

Figure 8 Packaging stamp

At Figure 8, the stamp on the jasmine tea package serves as the product's brand name. This stamp is designed in a square shape, providing a clear product identity while also enhancing the packaging's visual appeal, making it more recognizable to consumers. Each side of the stamp measures 4 cm in length.

Figure 9 Surface of cooking stove

At Figure 9, the cooking stove surface is designed in a circular shape. This stove serves as a place to hold charcoal during the tea cooking process. The surface of the cooking stove has a diameter of 40 cm.

Figure 10 Song

At Figure 10, Song is a cylindrical tool with a length of 3.5 meters and a diameter of 50 cm, used in the withering and drying process of tea leaves. This tool is designed to hold up to 15 kg of tea leaves during the process. The working mechanism of the song involves inserting tea leaves into the cylinder, then continuously rotating it without stopping. During this process, the song is heated over a wood fire to provide the necessary heat. This continuous and even heating ensures that the tea leaves undergo optimal withering and drying, preserving the tea's quality.

Figure 11 Song stove

At Figure 11, the song stove is a block-shaped tool used as a support for the song during the tea cooking process. The stove has dimensions of approximately 3 meters in length, 2.5 meters in width, and 1 meter in height.

b. Measurement

This is the process of making traditional tea that involves measurement.

Withering Process; In the withering process, there is a concept of weight and time measurement, namely measuring the weight of tea leaves to be placed into the song, which should weigh 15 kg. Meanwhile, the cooking process requires 15 minutes. This measurement is very important because the capacity of the song can only hold a maximum of 15 kg of tea leaves. If measurement is not carried out, the tea leaves placed inside may exceed the song's capacity, which can disrupt the withering process. Rolling Process; In the rolling process, there is a concept of weight measurement, which involves measuring the weight of the tea leaves to be placed into the rolling machine, which should be 70 kg. This measurement is important to ensure that the rolling process runs according to the capacity of the equipment used. Drying Process; The drying process involves the concept of weight measurement, which includes measuring the weight of the tea leaves to be placed into the song, which is 15 kg, as well as measuring the weight of the firewood used in the drying process, which is 9 kg. With precise measurement, the drying process can be carried out efficiently and produce optimal tea quality. If the measurement is not done correctly, both the tea leaves and the firewood may exceed the required capacity, which can affect the final tea production result. Cooking Process; In the cooking process, whether for original tea or jasmine tea, there is a concept of weight and time measurement. Weight measurement is used to measure the weight of the tea leaves to be cooked, which is 2 kg per batch. In addition, weight measurement is also used to measure the weight of the charcoal used in the cooking process. Time measurement is used to determine the cooking duration. In the cooking process of original tea, the required time for each batch is 12 minutes, with the rule that the tea leaves are flipped every 4 minutes. Meanwhile, in the cooking process of jasmine tea, the required time is 15 minutes, with the rule that the tea leaves are flipped every 5 minutes. In the second cooking process for jasmine tea, the cooking time is reduced to 10 minutes, with the tea leaves flipped every 3 minutes. Cooling Process; In the cooling process, there is a concept of time and weight measurement. Time measurement is used to determine the duration needed for the tea to reach the desired temperature. For original tea, the cooling process takes 10 minutes. Meanwhile, for scented tea, the first cooling process lasts 15 minutes, and the second cooling process lasts 10 minutes. In the cooling stage of original tea, there is no concept of weight measurement. However, in the cooling process of jasmine tea, both in the first and second cooling stages, there is a concept of weight measurement. Each tampir in the cooling process can hold 3 kg of tea leaves. Moisturizing Process; In the moisturizing process, there is a concept of weight and time measurement. Weight measurement is used to measure the weight of tea or jasmine leaves in one tampir, ensuring that the amount of tea leaves included in the moisturizing process matches the capacity of the tampir. Time measurement is used to measure the duration of the moisturizing process, which lasts 24 hours in each cycle. Packaging Process; In the packaging process, the concept of measurement is used to determine the product weight. For original tea, in 500-sized packaging, every 8 tea packages have a total weight of 1 ounce. Meanwhile, for 1000-sized packaging, every 4 packages also have a total weight of 1 ounce. For scented tea, each 1 ounce yields a different number of packages. In 500-sized scented tea packaging, 1 ounce produces 14 packages, while in 1000-sized packaging, 1 ounce produces 7 packages. This weight measurement is very important to ensure that the amount of tea packed corresponds to the designated weight, maintaining product consistency for consumers.

c. Proportion

In the traditional tea-making process in Banyumas, various examples of proportional relationships can be observed. A proportional relationship means that when one value increases, the other also increases at the same rate. For example, in the processing of raw tea leaves into semi-processed tea, every 3 tons of tea leaves require 4,900 kg of firewood. This creates a 3:4,900 ratio. If the amount of tea leaves increases to 6 tons, the amount of firewood required will also double, reaching 9,800 kg. During the withering and drying stage, every 15 kg of tea leaves requires 9 kg of firewood, forming a 5:3 ratio. If 30 kg of tea leaves are withered, then 18 kg of firewood is required, maintaining the same proportionality. In the semi-processed tea to final tea stage, different amounts of charcoal are needed depending on the tea type. For original tea, every 30 kg of tea requires 5 kg of charcoal, creating a 6:1 ratio. For jasmine tea, every 30 kg of tea requires 6 kg of charcoal, forming a 5:1 ratio. If the amount of processed tea doubles to 60 kg, then the required charcoal also doubles: 10 kg for original tea and 12 kg for jasmine tea. In the humidification process, every 3 kg of original tea requires 1.5 kg of jasmine flowers, forming a 2:1 ratio. If 6 kg of tea is processed, 3 kg of jasmine flowers will be needed. During packaging, for original tea: Every 1 ounce of tea produces 8 packs of 500-an or 4 packs of 1000-an (1:8 and 1:4 ratios). For jasmine tea: Every 1 ounce of tea produces 14 packs of 500-an or 7 packs of 1000-an (1:14 and 1:7 ratios). If the amount of processed tea doubles, the number of packages also doubles accordingly.

d. Decay

In the traditional tea-making process, decay (or material reduction) follows a mathematical formula describing how raw materials decrease at each stage. Processing tea leaves into semi-processed tea: Every 100 kg of raw tea leaves results in only 30 kg of semi-processed tea. This represents a significant decay in weight. Processing semi-processed tea into final tea: Every 30 kg of semi-processed tea results in 27 kg of original tea. For jasmine tea, 30 kg of semi-processed tea produces only 26 kg of final tea.At each stage, raw materials decay, reducing their weight as they undergo processing. The amount of final tea left after each stage follows a decay principle, where the remaining material M_n is calculated based on the initial material M_o and the decay rate.

e. Set Theory

In the humidification process of jasmine tea, we can see a simple application of set theory and union operations in mathematics. The union (A ∪ B) of two sets A and B includes all elements from set A, all elements from set B, and elements common to both sets. In this case: Set A represents tea. Set B represents jasmine flowers. The union (A ∪ B) represents the combined tea and jasmine flowers in a single tampir. During the 24-hour humidification process, jasmine flowers release their fragrance into the tea, merging the two elements into a single product fragrant jasmine tea. This illustrates how union operations in set theory describe how different elements (tea and jasmine flowers) can combine to create a new entity with enhanced properties.

D. Conclusion

The exploration of ethnomathematics in Banyumas' traditional tea-making processes revealed numerous embedded mathematical concepts, including geometry, measurement, ratios, decay, and set theory. In addition, ethnomathematical activities such as measuring, designing, calculating, and explaining were identified. These findings support the potential of integrating local cultural practices into mathematics instruction to enhance contextual and meaningful learning experiences.

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Investigating the Factors Contributing to Low Mathematics Performance in Tanzanian Ordinary Secondary Schools

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Abstract: This quantitative study aimed to investigate the factors contributing to low mathematics performance in secondary schools within Morogoro Municipality, Tanzania.. Relevant literatures reviewed on findings that emerged from different authors. The study involved in 3 secondary schools, 50 mathematics teachers and 150 students. These helped us to obtain numerical data through simple random sampling Data collection conducted by using questionnaires, then the data were analyzed using statistical package software (SPSS). It was found that teacher lack of professional training contribute to low performance in mathematics, inappropriate teaching methods effect on student's performance in mathematics, class size contribute to low performance in mathematics,, teaching materials and use of ICT contribute to high performance in mathematics, appropriate using teaching and learning resources in teaching Mathematics contribute to high performance, parental educational status contributes to low performance in mathematics, students' attitude towards mathematics contribute to low performance in mathematics, the teacher- student-relationship contribute positively or negatively towards low performance in mathematics subject, and classroom and school environment contribute either positively or negatively towards low performance in mathematics. These results have implication in improving performance in mathematics for students in secondary schools.

Keywords: mathematics; secondary schools; low performance

A. Introduction

Mathematics is the science of reasoning and computations. It is the science or study of numbers, quantities or shapes. Kitta (2004), defined mathematics as the language that helps us to describe ideas and relationships drawn from the environment. Mathematics enables one to make the invisible to be visible, thereby solving problems that would be impossible otherwise. However, mathematics is one of the subjects that students do not perform well in Tanzanian secondary schools. For example, the national examination results in percentages for Form II students in the past four years 2019, 2020, 2021, 2022 are 44.98%, 68.04%, 55.77%, and 56.56% respectively. Similar challenges exist for the Form IV national examination results. For example, mathematics overall performance in percentages for the same four years are 20.03%, 59.63%, 57.63%, and 49.70% respectively.

In Tanzania's education curriculum, mathematics is a core subject studied by both primary and ordinary secondary education students (ETP, 1995). In spite of being the core and compulsory subject, students' performance in Mathematics in Tanzania has been low for number of years in Certificate of Secondary Education Examinations (CSEE) (Kita, 2004; Mlozi, Kaguo & Nyamba, 2013; NECTA 2024; URT, 2008; SEDP, 2004). According to (URT, 2008), large number of students fail fail mathematics examinations, as the report indicated that national Form IV examination results in 2004, 2005 and 2006 failures in Mathematics were 70%, 77% and 76% respectively.

A report by HakiElimu (2013) identified that in 2009, about 27.5% of the students scored division zero in the year 2010 failure increased to 49.6%, in the year 2011 failure was 46.4% and 60.5% in the year 2012. The results have been improving in the past three years continuously due to government efforts including offering professional development for mathematics teachers. Although some improvements have occurred (NECTA, 2024). Therefore, this study investigated factors contributing to low performance in mathematics in ordinary secondary schools and the ways that low performance in mathematics can be improved in ordinary secondary schools.

B. Methods

This study employed quantitative method to collect and analyze numerical data (Creswell, 2014). This study also employed descriptive research design in order to describe the phenomena under study (Creswell, 2014).

The research site for investigating low performance in the mathematics subject was conducted in Morogoro Municipal to students and mathematics teachers in secondary schools by focusing to schools that have been achieving low performance in mathematics for Form IV National Examination Results.

Purposive and simple random sampling methods were employed.. Purposive sampling means that respondents are chosen on the basis of their knowledge of the information desired (Calderon, 1993). Moreover, random sampling was used in choosing sample unit from the entire population of teachers and students. Purposive sampling also was used in choosing education officials and head of schools as they were concern with monitoring of educational service in schools. It is a process of selecting number of individuals for a study in a way that the sample was represent the large group from where was selected. The researchers used a sample of 150 students and 50 teachers among of Morogoro municipal secondary schools.

Data collection refers to the process of gathering specific information aimed at proving or refuting some facts (Kombo & Tromp, 2006). The researchers used questionnaires for students and teachers to collect data. A questionnaire is an instrument containing a number of questions which participants have to complete either by ticking in the boxes or written information (Opie, 2007). The method is economical because respondents from distant locations can be reached and questions are standardized. The method assures confidentiality and exerts less pressure to the respondents a thing which helps to collect enough data because respondents do not become tired or get bored easily (Masudi, 1986). Administration of the questionnaires to respondents was done around school compounds in workdays to get the required respondents in the real school setting.

According to Kothari (2004), data analysis is a process of editing, coding, classification and tabulation of collected data. The process involves operations which are performed with the purpose of summarizing and organizing the collected data from the field. Since the study involved quantitative data, the data analysis process was done by using Mtitu (2015) as an analytical framework to describe the collected data in means, frequencies and percentages. Also, we used Statistical Packages for Social Sciences (SPSS) as a statistical tool for quantitative data analysis. The process involves coding of data, sorting and drawing conclusion.

C. Results and Discussion

1. Factors for Low Performance in Mathematics from Teachers' Perspective

a. Inappropriate Teaching Methods Effect on Student's Performance in Mathematics

Table 1. Inappropriate Teaching Methods Contribute to Low Performance in Mathematics

Inappropriate Teaching Methods Contribute to Low Performance in Mathematics	Frequency	Percent
Agree	38	76.0
Strongly agree	7	14.0
Disagree	1	2.0
Strongly disagree	4	8.0
Total	50	100.0

Table 1 revealed that majority representing (1%) of the students disagree that poor method of teaching affect students' performance in mathematics. (76%) agreed, and (7%) were strongly agree and 4% were strongly disagree on the matter that poor methods of teaching affect students' performance in mathematics. The study shows that majority of the respondents agreed that poor method of teaching affect students' performance in mathematics.

b. Teacher Lack of Professional Training Contribute to Low Performance in Mathematics

Table 2. Teachers Lack Professional Development Contribute Low Performance in Mathematics

Indicators		Frequency	Percent
	Agree	27	54.0
	Strong agree	15	30.0
	Disagree	8	16.0
	undecided	0	0
	Total	50	100.0

Table 2 revealed that majority representing (30%) of the students strongly agreed that lack of teachers for professional training contribute students' low performance in mathematics. (54%) agreed of the respondents, (0%) of the respondents were undecided while (16%) of the respondents disagreed teacher lack of professional training contribute students' performance in mathematics. Lack of teacher training, experiences and unqualified it difficult to solve problems encounters students, unable to prepare good lesson plan and notes, follow logical sequences of teaching in mathematics from simple to complex, using appropriate teaching mathematic method therefore contribute low performance Ritzika (2008).

c. Class Size Contribute to Low Performance in Mathematics

Table 3. Large Class Size Can Contribute to Low Performance in Mathematics

Participants' Responses on Large Class Size		Frequency	Percent
	Agree	26	52.0
	Disagree	19	38.0
	Strongly agree	5	10.0
	Strongly disagree	0	0
	none of those	0	0
	Total	50	100.0

Table 3 showedthat majority representing (52%) of the students agreed that class size contribute to low affects students' performance in mathematics, (10%) of the respondents strongly agreed, (0%) was none of these, (0%) of the respondents strongly disagreed while (38%) disagreed class size contribute to low affects students' performance in mathematics. These responses indicate that large number of students they are not comfortable when the class is too small than the number of students in the class during learning process which hinder them to interacts both students and teacher this contribute the low concentration of students, disturbances to other students. On the students' perspectives, the majority of the students with 26% alluded to the fact that there were no enough classroom spaces in the schools such that in some cases four pupils shared a desk meant for three students. Classes when overcrowded, therefore, the level of individual attention from the teachers is low. This finding is aligned with Wiliams (2001).

d. Teaching Materials and Use of ICT Contribute to High Performance in Mathematics

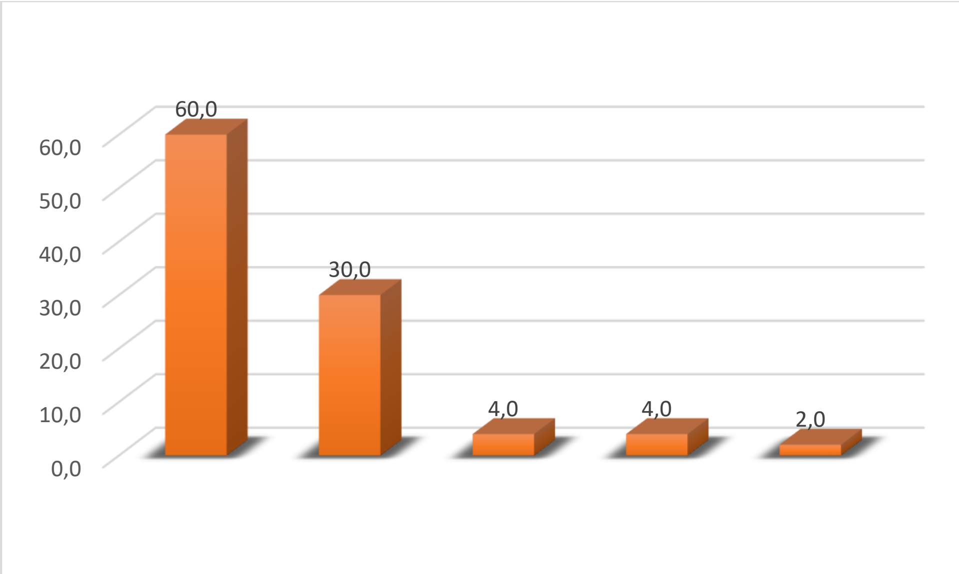

Figure 1. Participants' Responses on Teaching Materials and Using ICT in Teaching Mathematics

Figure 1 showed that (60%) of the respondents agreed to teaching materials and use of ICT contribute to high performance in mathematics, 4% of the respondents strongly agreed to the above claim, (2%) were undecided, (4%) of the respondents strongly disagreed while (30%) disagreed that teaching materials and using ICT affect students' performance in mathematics. This shows that majority of the respondents concurred with the fact that teaching materials and use of ICT contributed to low performance in mathematics students. Information communication technology (ICT) is a tool that can demystify the learning of Mathematics when integrated in the subject. Equipment's such as the interactive white board, digital projector, touchscreen among others are proving to ease the teaching of the subject. It enhances activity and is thus a student cantered way of learning from the forgoing it is evident that students' attitudes, teachers' beliefs about students and Mathematics, teaching methods and resource availability affect performance in Mathematics in a big way. The issue of attitude should be addressed by the administrators to reverse the trend. Even though the majority of teachers and students may not be using or even aware of the unique potential capabilities of computer technology in teaching and learning, the positive attitude towards computer use in education shows there is a bright future in teaching Mathematics. This will enhance improved performance in the subjects. The use of ICT in the mathematics classroom has primarily held of particular concern to mathematics educators. Some examples of the use of ICT in Mathematics are portable, graphic calculators, computerized graphing, specialized software, spreadsheets, and databases. This result aligns with Becta (2003).

e. Appropriate Using Teaching and Learning Resources in Teaching Mathematics Contribute to High Performance

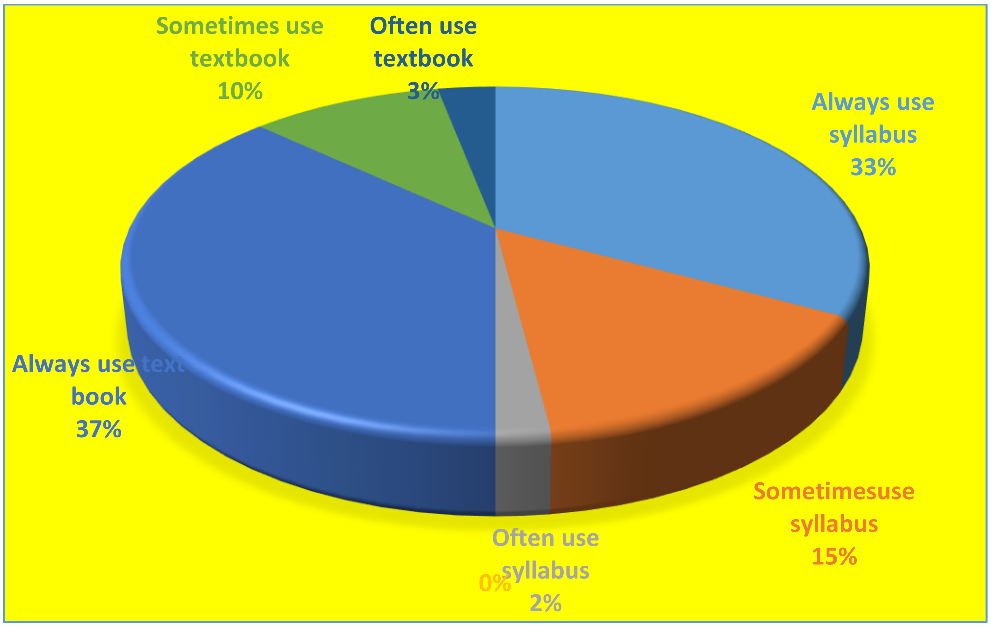

Figure 2. Appropriate Using Teaching and Learning Resources Contribute Good Performance

The findings of the study indicated that 33% of the respondents reported always using the syllabus, while 37% stated that they consistently used textbooks during teaching. Additionally, 15% reported using the syllabus sometimes, and 3% indicated that they often used textbooks. These responses suggest that the consistent use of the syllabus and textbooks during teaching and learning provides both teachers and students with a structured flow of instruction. This ensures that content is delivered appropriately according to the required level, avoiding materials outside the intended curriculum.

Furthermore, the highest percentage (37%) of teachers who responded to the questionnaire attributed the current poor student performance to a lack of resources. Libraries were reported to be poorly equipped, and the number of available textbooks was insufficient. Teachers highlighted this shortage as a major obstacle, noting that both students and educators lacked access to the relevant information necessary to perform well in examinations. Even in schools with libraries, supplementary materials were often unavailable. These educational resources are essential tools for student learning.

It was also found that many parents in the Morogoro District did not purchase mathematics textbooks for their children due to the government's inadequate supply. Textbooks play a crucial role in enabling students to follow the sequence of lessons presented by teachers and in facilitating understanding of the material. The shortage of textbooks left students at a disadvantage, limiting their ability to grasp lesson content, complete class exercises and assignments, and acquire the necessary academic vocabulary.

Another aspect contributing to the low performance of students was the syllabus. Nearly all pupils in the study admitted that they were unable to follow lessons because the content was perceived as "too difficult" for them. This was confirmed by teacher participants, who acknowledged that students with low academic performance often lacked fundamental skills in reading, writing, and mathematics. These deficiencies made it extremely challenging for them to achieve the desired learning outcomes or follow the prescribed syllabus.

Despite teachers' efforts to simplify lessons and provide a minimally adequate syllabus for struggling students, many continued to face difficulties in absorbing content due to poor comprehension and learning skills. An overly complex or poorly structured syllabus often leads to confusion and disengagement, which negatively impacts student performance. Moreover, this impedes meaningful integration between teachers and students, undermining the creation of a cohesive learning environment.

Teachers also emphasized the importance of aligning textbooks with the syllabus to help students follow the curriculum more easily. In fact, 33% of respondents disagreed with the current textbook usage due to discrepancies between the syllabus and available textbooks, which they noted could confuse students and disrupt the learning process.

Eshiwani (1981) argued that poor performance in mathematics is often linked to inadequate textbooks, teaching aids, and learning resources. He further asserted that the proper use of textbooks and other instructional materials significantly enhances academic standards and the overall efficiency of a school system (Eshiwani, 1990). This view is supported by Anioke and Chigbou (2016), who emphasized that well-planned and purposeful use of teaching and learning resources can supplement and strengthen a teacher’s instructional capacity in the classroom. Similarly, the Ministry of Higher Education, Science and Technology (2010) highlighted the importance of presenting mathematical concepts in a logically sequenced manner to support student understanding.

f. Parental Educational Status Contributes to Low Performance in Mathematics

Table 4. Parental Educational Status Contributes Either Positively or Negatively in Low Performance in Mathematics

Indicators		Frequency	Percent
	Strongly agree	16	32.0
	Agree	19	38.0
	Slightly	10	20.0
	disagree	5	10.0
	Total	50	100.0

The respondents indicated that 32% strongly agreed, 38% agreed, 20% slightly agreed, and 10% disagreed that parental educational status contributes to students' low performance in mathematics. These responses suggest that a significant proportion of students believe that their parents’ level of education negatively affects their academic achievement. This finding reflects the high illiteracy rate in the study area, where many parents may not serve as effective academic role models for their children.

Desarrollo (2007) emphasized that the extent to which parents or other family members are actively involved in a student's education has a positive influence on student achievement. Conversely, low parental educational attainment can act as a constraint, limiting the academic performance of students. Children raised in insecure environments influenced by detrimental parental practices—such as cattle rustling, early marriages, and female genital mutilation (FGM)—often experience emotional and psychological challenges in school. These children tend to struggle with concentration in class and may lack the confidence needed to complete academic tasks effectively (Durojaiye, 1976).

Academic performance among students from such backgrounds tends to be consistently low. According to Conger et al. (1992), low parental educational status is associated with limited household resources, which in turn contributes to lower academic achievement.

Table 4 presents data on the educational background of students' parents or guardians. A substantial proportion (32%) of students reported that their parents or guardians did not attain education beyond secondary school. This finding further reflects the high illiteracy rate in the study area.

The level of parental education was found to be a significant factor influencing students' academic performance in mathematics. This aligns with the findings of Coleman (1966) and Campbell, Hombo, and Mazzeo (2000), who also concluded that parental education plays a crucial role in shaping students' academic success. Parents with higher levels of education are more likely to serve as positive academic role models and support their children in achieving higher performance, particularly in mathematics.

g. Class Regularity Affects Students' Low Performance in Mathematics

Table 5. Class Learning Environment Contributes Either Positively or Negatively Towards Low Performance in Mathematics

Indicators		Frequency	Percent
	To great extent	18	36.0
	quite a lot	15	30.0
	To some extent	9	18.0
	some how	6	12.0
	not at all	2	4.0
	Total	50	100.0

Table 5 shows that 36% of respondents believed class regularity affects performance to a great extent, 30% said quite a lot, 18% to some extent, 12% somehow, and 2% not at all.

These findings indicate that regular attendance is perceived as a major factor influencing academic achievement. Numerous studies have shown a positive correlation between consistent school attendance and academic performance, particularly in mathematics. Regular attendance ensures that students are consistently exposed to instructional content, can actively participate in classroom discussions, and receive timely feedback from their teachers.

This continuous engagement reinforces students' understanding of mathematical concepts, which are often cumulative in nature. However, poor scheduling of remedial or regular mathematics classes—such as assigning math sessions in the afternoon—can reduce student attentiveness. Fatigue, especially during calculation-heavy lessons, contributes to diminished concentration and performance.

In the Morogoro District, 36% of students reported attending school regularly, compared to only 2% in high-achieving schools, highlighting a potential relationship between attendance frequency and school performance levels. This observation aligns with the findings of Stigler and Perry (1988), who emphasized that student involvement in classroom activities is a key determinant of academic success.

A conducive classroom environment should support learning by fostering high expectations, encouraging self-regulation, and clearly communicating academic standards. Ryan (2011) further noted that without proper class scheduling and structure, students may experience poor time management, which negatively impacts both teaching and learning processes.

2. Factors Contributing Low Performance in Mathematics from the Students' Perspectives

a. Students' Attitude Towards Mathematics Contribute to Low Performance in Mathematics

Table 6. Students' Attitude Towards Mathematics Contribute to Low Performance in Mathematics

Students' Responses	Frequency	Percent
Agree	78	52.0
strongly agree	25	16.7
Disagree	26	17.3
strongly disagree	12	8.0
none of those	9	6.0
Total	150	100.0

Table 6 shows that 52% of respondents agreed, 16% strongly agreed, 17.3% disagreed, 17.7% strongly disagreed, and 6% selected "none of the above." These results indicate that a majority of students (52%) acknowledged a relationship between their interest in studying mathematics and future employment opportunities. A perceived lack of job prospects after completing mathematics education was cited as a factor discouraging student motivation and performance in the subject.

In addition, some students expressed disinterest in mathematics due to their belief that it is more difficult than other subjects, particularly because of the numerous formulas involved. Mutondi and Ngirande (2014) observed that many students perceive mathematics and science as difficult and boring subjects, which leads to the development of negative attitudes and subsequently poor performance. This finding aligns with the current study, which revealed that a significant proportion of students (52%) considered mathematics a difficult subject.

Muthaa and Nkonke (2012) also emphasized that negative attitudes toward mathematics contribute directly to low academic performance. During interviews, one school principal noted that fostering a positive attitude among students requires strategic efforts by both teachers and parents, including consistent encouragement and administrative support. However, students often feel that science subjects are too challenging, and the language used in instruction is difficult to comprehend, further compounding the learning barriers.

Teachers also face obstacles, such as insufficient resources, including textbooks and laboratory equipment. In some schools, students encounter educational tools and materials for the first time during examinations, which negatively affects performance since they lack prior hands-on experience or practical exposure to mathematical applications.

To address this, educational administrators must take deliberate steps to reshape students' attitudes toward mathematics. Although most teachers and students may not yet utilize or even be aware of the full potential of computer technology in education, the generally positive outlook on integrating ICT in learning environments offers promise for the future. Embracing such innovations could help improve student engagement and achievement in mathematics.

b. Parents' Guide Students to Study at Home

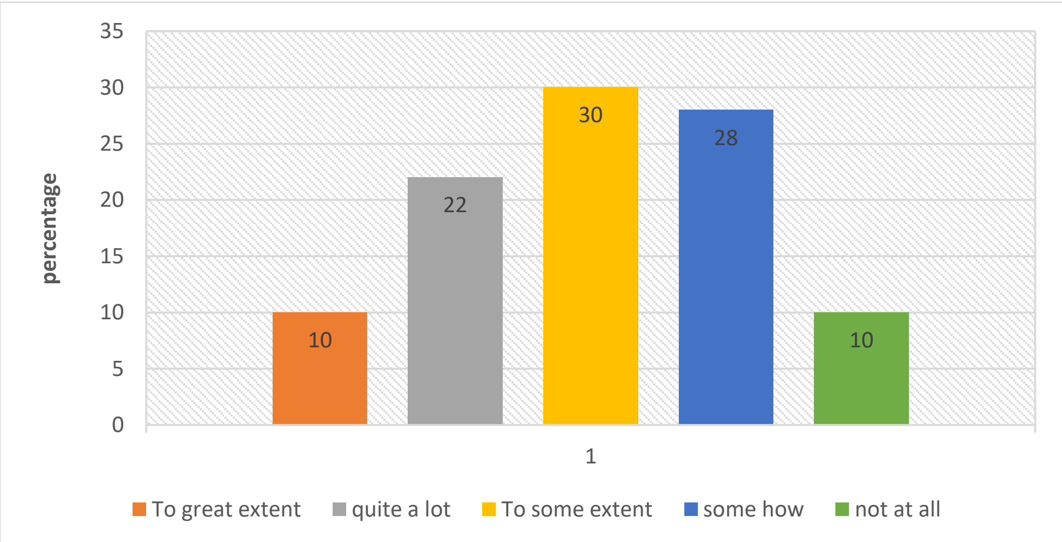

Figure 3. Parents' Responsibilities for Students

Results from Figure 3 indicate that 30% of respondents believed most parents or guardians do not adequately care for their children's education at home. Additionally, 28%

responded “somehow,” 22% “quite a lot,” and 10% “to a great extent.” The data suggest that many parents/guardians do not allocate sufficient time for their children to study, instead assigning domestic responsibilities that limit students’ study time. This trend may reflect the high illiteracy rate in the study area, where parents may lack the awareness or capacity to serve as effective academic role models.

Desarrollo (2007) asserted that the extent to which parents or other family members are actively involved in a student’s education has a positive impact on academic achievement. Although some parents do provide adequate time and support for their children to study mathematics at home, this is not universally the case. In many instances, students are required to assist their parents with business activities, such as working at local markets, resulting in late returns home and physical exhaustion. Consequently, these students have minimal time or energy left to dedicate to academic study.

Moreover, many families struggle to meet the basic needs related to schooling, contributing to poor academic outcomes and even school dropout. Onu and Mezieobi (2015) found that parental behaviors such as rewarding learning-related actions, providing verbal encouragement, praising efforts, ensuring proper nutrition, offering educational materials, helping with homework, and showing emotional support at home significantly contribute to students' motivation and academic performance.

The present findings emphasize the critical role of parental engagement in mathematics education. The study revealed that students’ interactions with their parents strongly influence their motivation to learn. Specific forms of parental social support—including encouraging learning behaviors, assisting with school assignments, maintaining school communication, paying school fees on time, ensuring proper school attire, and supporting home-based learning—can significantly boost student motivation (Igbo, Odo, Onu, & Mezieobi, 2015).

Henderson and Berla (2004) also argued that the strongest predictor of student achievement is not family income or social status, but the extent to which families create a supportive learning environment at home, communicate high academic expectations, and remain actively involved in school activities. Similarly, Ryan (2005) reported that students with parents who enforce clear academic rules and structure at home tend to perform better in school.

These findings underscore the importance of parental involvement in various aspects of their children's education, including daily attendance, academic achievement, classroom behavior, and motivation. Based on this evidence, the current study aimed to further examine the influence of parental involvement on students’ academic performance in mathematics.

c. Students' Abilities and Confidence in Solving Mathematical Problems

Table 7. Students' Abilities and Confidence in Solving Mathematics Problems

Students' responses	Frequency	Percent
very confident	61	40.7
confident	49	32.7
neutral	26	17.3
not very confident	9	6.0
not confident at all	5	3.3
Total	150	100.0

The respondents reported varying levels of confidence in learning mathematics: 40.7% stated they were very confident, 32.7% confident, 17.3% neutral, 6% not very confident, and 3.3% not confident at all. The 40.7% of students who felt very confident suggest that a substantial portion of learners are able to solve mathematical problems effectively during the learning process. This may be attributed to a strong foundational understanding acquired in primary school and sufficient literacy in the language used in mathematics instruction.

Conversely, the 3.3% of students who reported not being confident at all indicates a group of learners who struggle significantly with mathematics. These students may lack interest or self-belief, often perceiving mathematics as overly difficult and doubting their ability to overcome its challenges or make progress. This highlights the crucial role of individual student effort in academic success.

To support such students, it is important to create learning experiences that build interest and confidence. One approach, as demonstrated in a study by Hassan and Mahmud (2018), involves integrating information technology—such as tablet-assisted instruction—into the mathematics classroom. Their research showed that this method had a significant positive impact on the confidence and interest of slow learners.

Based on research conducted in Vietnam, the characteristics of slow learners in mathematics can be categorized into several dimensions: (1) **Attitude**: These students may listen attentively but fail to grasp the teacher's explanations. Some show apathy during lessons, display low interest in mathematics, or suffer from low self-esteem and a lack of confidence in their abilities; (2) **Cognitive approach**: They tend to rely on rote memorization of formulas and concepts rather than understanding underlying principles. This mechanical thinking limits their ability to apply knowledge to problem-solving tasks; (3) **Knowledge gaps**: Many slow learners have significant gaps in foundational knowledge, struggle to comprehend conceptual relationships, and fail to connect properties and theorems meaningfully; (4) **Mathematical skills**: These students often have poor abilities in expressing mathematical ideas, weak conceptual linkage, and difficulty solving problems independently. Their pace of learning is slower than that of their peers, and they often exhibit weak group interaction and delayed responses; and (5) **Learning methods**: Slow learners usually lack effective learning strategies and may not respond well to conventional teaching methods. Their academic performance typically includes consistently low scores across various mathematical domains, although some may perform better in specific topics.

These observed traits and patterns align with the findings of Thanh et al. (2015), who emphasized the importance of identifying and classifying slow learners in order to design appropriate support strategies. A deeper understanding of these learner characteristics can help educators provide targeted interventions that foster better engagement, confidence, and academic achievement in mathematics.

d. Classroom and School Environment Contribute Either Positively or Negatively Towards Low Performance in Mathematics

Table 8. Classroom and School Environment Contribute Either Positively or Negatively Towards Low Performance in Mathematics

Students ‘responses		Frequency	Percent
	agree	44	29.3
	disagree	45	30.0
	strongly agree	37	24.7
	strongly disagree	16	10.7
	none of those above	8	5.3
	Total	150	100.0

Table 8 shows that 30% of participants disagreed, 29.3% agreed, 24.7% strongly agreed, 10.7% strongly disagreed, and 5.3% selected “none of the above.” These results indicate that while a notable portion of students agreed that a conducive learning environment supports performance in mathematics, the majority felt that such an environment was lacking in their schools.

A positive and supportive physical environment—characterized by adequate infrastructure, well-ventilated classrooms, sufficient lighting, and manageable class sizes—can significantly contribute to student performance. When classrooms are overcrowded or poorly maintained (e.g., lacking windows or lighting), students often struggle to concentrate and participate in discussions effectively, which leads to poor academic outcomes in subjects like mathematics.

School environmental factors refer to both the **quality of physical infrastructure** and the **perceptions students hold** about their learning setting. These factors include the availability of teaching and learning materials, the school’s location, the quality of facilities, classroom organization, class size, and teacher qualifications. Classrooms should be organized to facilitate effective use of resources. For example, labeled storage areas, shelves, manipulatives, and designated student-teacher conference zones help maintain structure and clarity within the learning space.

School-level support also includes the preparation and vetting of lesson notes, ongoing in-service teacher training, and regularly scheduled staff meetings. The school's location and overall physical appearance can influence student motivation. Specifically, unattractive school buildings and inconvenient locations may reduce student interest and attendance, ultimately affecting academic performance.

An important aspect of the learning environment is the relational climate—often described as the "caring classroom." Relationships between teachers and students play a central role in fostering a productive learning atmosphere. As highlighted by Lewis, Schaps, and Watson (1996), caring relationships in school are associated with higher academic achievement, increased student motivation, greater engagement in school activities, and fewer behavioral issues. In such classrooms, every student feels valued and encouraged to contribute.

According to Noddings (1993), there are two critical dimensions of care in education: students' perception of being cared for, and their ability to care for others. However, when class sizes exceed optimal numbers, it becomes difficult for teachers to provide individualized support—particularly to academically weaker students. Additionally, some students choose to skip classes in favor of income-generating activities, such as selling goods in town, further compromising their academic progress. Creating a safe, trusting, and collaborative classroom environment is essential to encouraging student engagement and improving outcomes in challenging subjects like mathematics.

e. Lack of Classroom Motivation Contributes to Low Performance in Mathematics

Table 9. Inappropriate Classroom Causes Low Performance in Mathematics

Indicators		Frequency	Percent
	agree	50	33.3
	strongly agree	42	28.0
	disagree	35	23.3
	strongly disagree	14	9.3
	none of those above	9	6.0
	Total	150	100.0

The majority of participants disagreed with the statement that they were motivated by their mathematics teachers and school leaders. Specifically, 9.3% strongly disagreed, while 33.3% agreed that they were not motivated by their mathematics teachers in the classroom. Interestingly, all teachers from the three selected schools reported that they did, in fact, attempt to motivate their students. According to these teachers, motivation plays a critical role in improving student performance, as it fosters a competitive and engaging learning environment in which students strive to gain praise and recognition.

Students can be motivated to learn mathematics through the provision of rewards such as mathematical sets, calculators, and textbooks. These tools not only serve as incentives but also enhance students' ability to engage with the subject matter effectively, ultimately contributing to better academic outcomes.

However, the use of corporal punishment in classrooms—where students are physically punished, for example, with sticks for making mistakes—was highlighted as a detrimental practice. Instead of encouraging students, such punishment often results in fear and resentment, leading to decreased motivation and reduced effort in studying. In contrast, positive reinforcement, such as praise or tangible rewards, is more likely to foster student engagement and persistence.

Higher failure rates in mathematics have also been linked to low levels of motivation among teachers themselves. Factors such as teachers' attitudes toward students and mathematics, ineffective instructional strategies, weak content knowledge (Mazana et al., 2019; Michael, 2015), and teachers' emotional states in the classroom (Frenzel et al., 2009; Klusmann et al., 2008) can all impact the learning environment. When teachers lack enthusiasm or confidence, students are less likely to be inspired or supported in their learning.

Therefore, enhancing both student and teacher motivation is essential in improving mathematics performance. A supportive, respectful, and reward-based classroom environment—paired with well-prepared and emotionally responsive teachers—can greatly contribute to student success in mathematics.

f. Teacher's Behavior Contributes Either Positively or Negatively Towards Low Performance in Mathematics

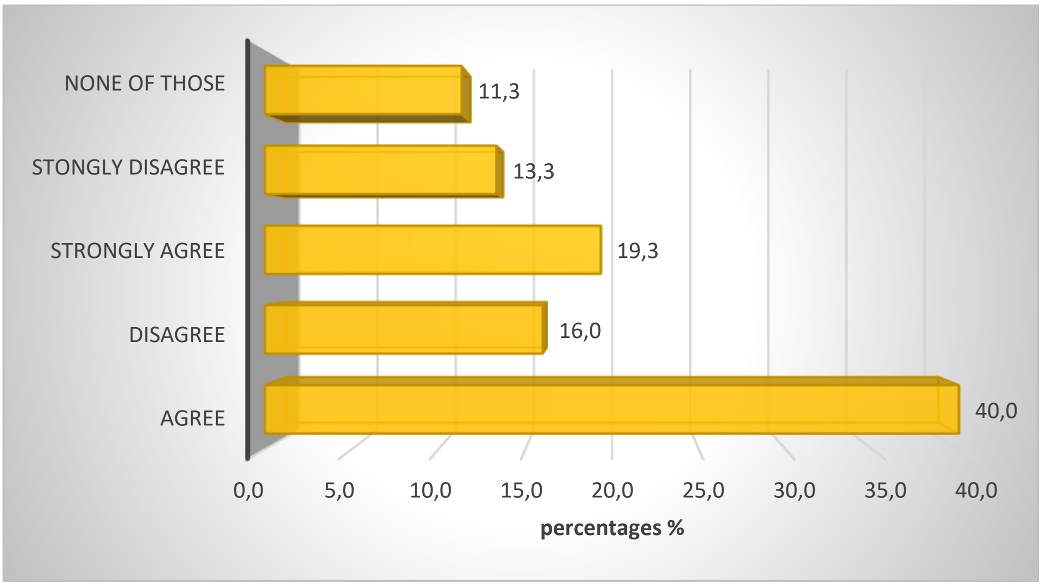

Figure 4. Teacher's Behavior Contributes Either Positively or Negatively Towards Low Performance in Mathematics.

The respondents answered the question as follows: 40% agreed, 19.3% strongly agreed, 16% disagreed, 13.3% strongly disagreed, and 11.3% selected "none of the above." The 40% who agreed indicate that teacher behavior can significantly impact students' performance in mathematics at the secondary level. In particular, a lack of enthusiasm or failure to make the subject engaging can result in students perceiving mathematics as dull and uninteresting.

Behavioral engagement refers to students' involvement in academic, social, and extracurricular activities (Hughes, Luo, Kwok, & Loyd, 2008). It comprises three key components: (1) **Learning-related behaviors**, including effort, persistence, concentration, attention, asking questions, and contributing to classroom discussions; (2) **Compliance behaviors**, which involve adherence to school rules and expectations, as well as avoidance of misbehavior such as skipping class or frequent absenteeism; (3) **Participation in extracurricular activities**, which supports holistic development and school connectedness; (4) **Affective engagement** involves students' emotional responses to people and activities in the school environment. It reflects how students feel about school, including their sense of belonging, safety, comfort, pride in the institution, and the quality of their relationships with teachers and peers (Hughes et al., 2008); and **Cognitive engagement** is related to the degree of mental effort and motivation students invest in their learning. It includes how much students value academic achievement, their desire to earn good grades, their willingness to complete tasks, and their tendency to go beyond minimum expectations.

Together, these three dimensions of engagement—behavioral, affective, and cognitive—provide a comprehensive understanding of students' connections to their school environment and their academic experiences (Sciarra & Seirup, 2008).

g. School Management System Support Either Positively or Negatively Towards Student's Performance in Mathematics

Table 10. Students' Responses Results for School Management System

Indicators		Frequency	Percent
	agree	69	46.0
	strongly agree	34	22.7
	disagree	27	18.0
	strongly agree	11	7.3
	undecided	9	6.0
	Total	150	100.0

The respondents' answers to this question were as follows: 46% agreed, 22% strongly agreed, 18% disagreed, 7.3% strongly disagreed, and 6% were undecided. These results indicate that the majority of respondents believed poor school management contributes to low student performance in mathematics. However, 6% felt that school management had no effect and instead believed that students themselves were primarily responsible for their academic success through personal effort and self-discipline.

A well-functioning **School Management System (SMS)** involves various administrative tasks, including student registration, attendance tracking, report card generation, transcript preparation, timetable creation, and reporting to teachers, parents, educational bureaus, and other stakeholders. The presence of an effective school management system can significantly improve academic outcomes, including mathematics performance.

The importance of administrative support has been emphasized in previous research. Ghavifekr et al. (2014) found that a lack of administrative support—such as limited resources and overwhelming workloads for both teachers and students—creates challenges for school management and hinders academic performance. In effective schools, decision-making bodies such as the school board, management team, teachers, student councils, and parents are actively involved in governance. When this inclusive approach is absent, it negatively impacts school performance and student achievement.

Invalsi and Grassetti (2003) investigated the role of school leadership across 18 countries and found a strong relationship between school head actions, students' backgrounds, and academic performance. They concluded that school leaders can directly influence student achievement through teaching, mentoring, and academic planning. Good school leadership contributes to overall school improvement by promoting teacher motivation, encouraging participation, and coordinating instructional activities. The time and focus that school leaders dedicate to academic affairs play a critical role in elevating student performance.

Moreover, school schedules and instructional planning should avoid overburdening students with overly complex content. Instead, incorporating enjoyable, creative, and innovative activities can help capture students' attention and enhance learning motivation. Providing differentiated instruction or tailored modules for low-performing students can improve their self-esteem and academic confidence.

Finally, teachers' insights, instructional techniques, and innovative ideas should be valued and integrated into school improvement strategies. Encouraging teacher participation in the development of instructional practices is essential for enhancing both the teaching process and student learning outcomes.

h. Ways to Improve Mathematics Subject Performance in Secondary Schools for Students

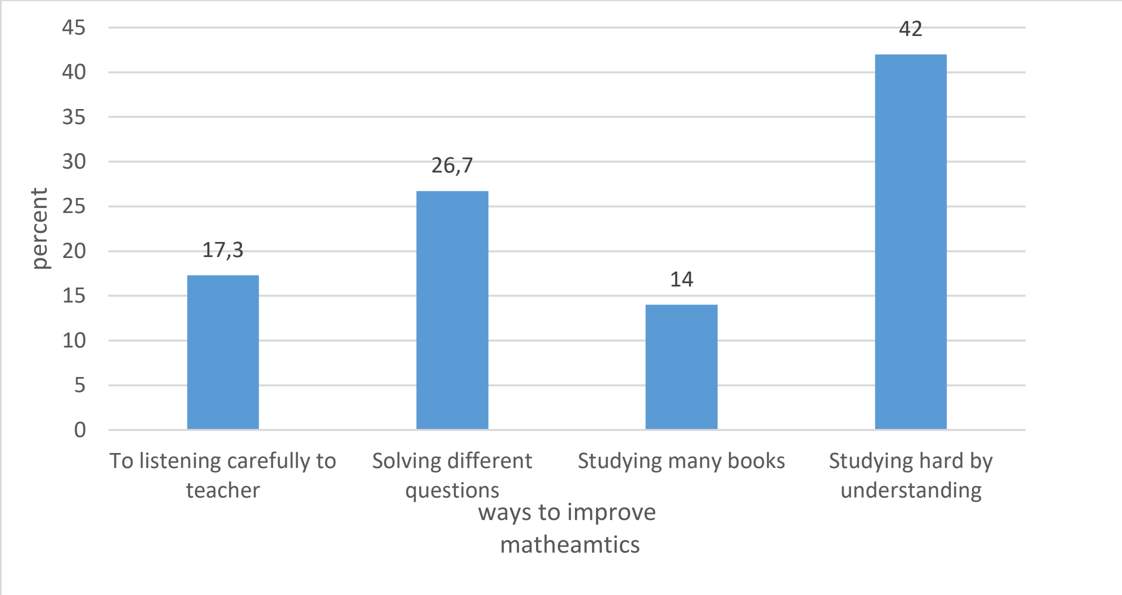

Figure 6. Appropriate Ways to Improve Mathematics Performance

The respondents answered the question as follows: 42% reported that they study hard by understanding the material during mathematics lessons, 26.7% emphasized solving different equations carefully with teacher guidance, 17.3% preferred to listen attentively, and 14% reported studying from multiple books. Notably, 42% indicated that they avoid rote memorization (commonly referred to as “creaming”) and instead focus on understanding concepts during teaching and learning processes.

These findings suggest that a significant number of students prefer to study mathematics through deep understanding rather than through memorization. This approach enables them to solve various types of problems more effectively and enhances their overall problem-solving skills and mathematical performance. Regular practice, coupled with a conceptual understanding of mathematical formulas and their application, allows students to apply their knowledge to a wider range of questions. In contrast, rote memorization without comprehension often results in poor performance, as students struggle to apply memorized procedures to unfamiliar problems.

Mathematics is inherently abstract and involves complex concepts such as symbols, numbers, and equations, which can be challenging for many students. Unlike some subjects that are more concrete, mathematics requires a high level of logical reasoning and conceptual understanding. For this reason, learning mathematics with understanding—as opposed to memorization—is strongly advocated by leading educators and researchers and is reflected in national goals and standards for mathematics and science education (American Association for the Advancement of Science, 1989, 1991, 2000; National Research Council [NRC], 1996).

Therefore, learning through understanding positively influences students' ability to solve various mathematical equations, as indicated by the 26.7% of respondents. However, some students still believe that studying many textbooks will improve their performance. While reading widely may enhance general knowledge, not all content covered in books directly correlates with what appears in tests or examinations. In mathematics, depth of understanding and targeted practice are more critical to success than broad but superficial reading.

D. Conclusion

This study focused on investigating the factors contributing to low performance in mathematics among secondary school students in the Morogoro District. The findings revealed several key factors: lack of professional training among teachers, inappropriate teaching methods, and large class sizes were all identified as contributing to low mathematics performance. In contrast, the use of appropriate teaching materials and information and communication technology (ICT) was found to enhance students' academic outcomes in mathematics. Additional factors influencing performance included insufficient use of teaching and learning resources, low parental educational status, irregular class attendance, negative student attitudes toward mathematics, lack of confidence in solving mathematical problems, and inadequate classroom motivation.

Based on these findings, it is recommended that addressing low achievement in mathematics at the secondary school level requires innovative and transformative approaches. Teachers should be encouraged to adopt modern teaching strategies, including the integration of computer-assisted instruction, to stimulate interest and maintain student engagement in mathematics and science subjects.

Furthermore, the government should implement supportive policies that promote the teaching and learning of mathematics. Investment in infrastructure is necessary to ensure that mathematics teachers have access to conducive teaching environments, which are critical for improving student performance.

In addition, guidance and counselling units should be established in secondary schools to provide academic, personal, and social support for students struggling with mathematics. These services can help students develop a more positive attitude toward the subject, ultimately improving their confidence, motivation, and academic achievement.

Acknowledgement

We acknowledge students and mathematics teachers who volunteered participating in this study.

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Enhancing Junior High School Students' Mathematical Understanding through Augmented Reality Media Using Assemblr Edu: A Development Study

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Abstract: Mathematical understanding ability is one of several basic mathematical abilities to be mastered and improved by students. Good mastery of this ability can support the development of advanced mathematical abilities. However, the students at SMPN 1 Paguyangan demonstrated low levels of mathematical understanding, which was partly due to monotonous lecture-based instruction and the rare use of interactive media to aid comprehension. This study aimed to develop Augmented Reality (AR)-based mathematics learning media using Assemblr Edu that were valid and effective in improving the mathematical understanding ability of ninth-grade students at SMPN 1 Paguyangan. The study employed a Research and Development (R&D) approach using the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). The results showed that the AR-based mathematics learning media developed using Assemblr Edu for the topic of "Three-Dimensional Shapes with Curved Surfaces" were declared valid and feasible, with scores of 80% from material experts, 91.6% from media experts, and 94.5% from mathematics teachers. Student responses were also positive, with average scores of 80.54% in the small group test and 78.48% in the field test. Furthermore, the pretest and posttest data were analyzed using an independent samples t-test, which produced a significance value of 0.000 ($p < 0.05$), leading to the rejection of H_0 and acceptance of H_1. The experimental group achieved an average N-Gain score of 0.771 (categorized as "High"), while the control group obtained a score of 0.357 ("Medium"), indicating that the developed learning media effectively improved students' mathematical understanding.

Keywords: assemblr edu; augmented reality; learning media; mathematical understanding ability

A. Introduction

Mathematics learning is a complex endeavor that involves developing new ideas by building skills, using algorithms, and following certain procedures (Anderson, 2007). Mathematics learning provides opportunities for students to participate actively, ask questions, and express opinions to develop their mathematical abilities (Gusteti & Neviyarni, 2022). In understanding the subject matter of mathematics in the learning process, students are expected to master mathematical understanding skills (Khoerunnisa & Hidayati, 2022). When learning mathematics, it is very important to understand mathematical understanding because mathematical understanding is the foundation of learning mathematics, so that it can help understand the purpose of learning mathematics and understand how mathematical logic works in dealing with everyday problems (Kharis et al., 2021).

Mathematical understanding ability is the goal of the mathematics learning proces (Riyanti & Zitouni, 2023). Mathematical understanding ability is the goal to show the ability to understand concepts, distinguish a series of mutually exclusive concepts, and the ability to perform meaningful calculations in more varied problems (Adella Nur Afinda, 2023). According to the opinion of Hendrina, Rohaeti, and Sumarmo, mathematical understanding ability is a basic ability in mathematics learning, including the ability to absorb concepts, remember them, apply them, and assess their correctness in solving problems (Hendriana et al., 2017).

Mathematical understanding ability has several important indicators that are used as a reference by teachers in developing mathematics materials. Based on NCTM, Director General of Education Regulation Number 506/C/Kep/PP/2004, and Sanjaya, researchers summarized the indicators of mathematical understanding ability, namely: (1) restate a concept, (2) classify objects according to certain properties, (3) present concepts in the form of mathematical representations, (4) apply concepts or algorithms in problem solving, (5) develop necessary or sufficient conditions for a concept (Hendriana et al., 2017).

The researchers conducted an initial observation on September 30, 2024, with Heru Subroto, S.Pd., a mathematics teacher for ninth grade at SMPN 1 Paguyangan, to identify students' learning problems through interviews and classroom observation. The results indicated that students' mathematical understanding was still at a low level. It was reported that many ninth-grade students struggled to grasp mathematical concepts. Several factors contributed to this low level of understanding. First, the teaching methods applied remained conventional, and the use of innovative learning media was minimal. Teachers primarily focused on delivering theories and formulas without connecting them to real-life contexts that could help students better understand their applications. Second, many students were not motivated to learn mathematics. This was further supported by preliminary test results conducted in class IX J, where 30 students achieved an average score of only 42.7 on a mathematical understanding test, categorized as low. When solving math problems, some students were still confused about identifying the known information and determining what was being asked. Additionally, most students experienced difficulties in outlining the steps required to solve the problems. The low level of students' mathematical understanding was also attributed to the teacher's reliance on conventional learning approaches. Most of the problems given only tested memorization, and learning media that could help deepen students' conceptual understanding had not been utilized.

Low student understanding of the success or failure of the learning process is not only motivated by factors from within the student such as intelligence in practicing, personal factors, motivation, and maturity in growth. But it is also motivated by factors from outside students such as family conditions, community environment, teacher teaching methods, learning media, and social motivation (Purwanto, 2007). One solution to low student understanding is the use of learning media. Learning media are all things that can be used to convey learning materials in order to arouse students' interest and attention, as well as influence their thoughts and feelings in the learning process so as to achieve the desired learning objectives (S. Wulandari et al., 2023). Learning media is one of many elements that play an important role in the teaching process. When teachers conduct learning, they generally use learning media as a medium for delivering material so that students understand it more easily. The use of learning media in the teaching process can foster new interests and desires, stimulate motivation, and even have a psychological impact on learning (Sya'diyah & Arifin, 2024). Therefore, in order to achieve learning objectives, media selection must be carried out very carefully and appropriately, so that the learning process can increase the effectiveness, efficiency, and attractiveness of learning (A. P. Wulandari et al., 2023).

One strategy to overcome the problem of selecting learning media is to improve teachers ability to develop learning media based on information technology and Augmented Reality, so that it can support effective and efficient learning in the era of technological disruption (Meriyati et al., 2024). Technological advances represented by Augmented Reality (AR) have brought significant changes to various aspects of human life, including education, which opens up new opportunities for progress and development (Nafi'ah et al., 2022). The emergence of a technology known as Augmented Reality (AR) combines 3D or 2D objects with the real world, so that people can interact with computers in a more natural way. Augmented Reality (AR) is a technology that integrates virtual objects either two-dimensional or three-dimensional, then projects those virtual objects into real time(Sari et al., 2022).

When the world is getting more complex and sophisticated and competition in the industrial sector to dominate the market is getting tighter (Arena et al., 2022). D or 2D manufacturing applications strive to present products that are sophisticated and easy to use (Syed et al., 2023). Currently, there are a number of AR application programs implemented, such as Unity3D, Blender, Sketchup, Vuforia, SDK, and Assemblr. The selection of Assemblr as a learning media application compared to other AR applications is due to the advantages of Assemblr AR, including: equipped with video, audio animation, does not require knowledge of programming, can display digital content anywhere and anytime, either in formal environments such as classes, books or in informal environments such as rooms or courtyards, and so on, and this AR application is specifically designed for the world of education (Suhati et al., 2023). Thus, the creation of 3D or 2D media is in line with the material received by students of class IX mathematics in even semesters is the curved side of the room (Kebudayaan, 2017).

Augmented Reality-based math learning media is a tool to deliver mathematical materials and concepts to students with the use of electronic devices such as mobile phones or laptops that can access a combination of real and virtual objects to improve the quality of learning and achieve learning objectives. This effort is supported by the results of research by Nur Indah Larasati and Nurbaiti Widyasari in 2021 which shows that Augmented Reality learning media can optimize students' mathematical understanding abilities, but there are no differences in students learning styles (Larasati & Widyasari, 2021). Therefore, Augmented Reality-based mathematics learning media using Assemblr Edu is a mathematics learning media developed by educators containing a series of learning objectives to achieve learning objectives using electronic devices such as mobile phones or laptops. As a result, researchers developed the same thing on curved-sided space building material to optimize students' mathematical understanding abilities in class IX.

Based on this background, the researcher was interested in developing Augmented Reality (AR) as an alternative medium for learning mathematics. This study was entitled: **"Development of Augmented Reality-Based Mathematics Learning Media Using Assemblr Edu to Improve Mathematical Understanding on the Topic of Curved-Surface Solids in Grade IX.**

B. Methods

1. Type of Research

This study employed development research, or Research and Development (R&D), which uses systematic methods to develop and evaluate the effectiveness of a product in order to assist teachers in improving the quality of learning (Sugiyono, 2013).

2. Research Procedure

The product developed in this research was Augmented Reality-based mathematics learning media using Assemblr Edu. The development model applied in this study followed the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. (Suryani et al., 2018).

3. Place dan Time of Research

This research was conducted at SMP Negeri 1 Paguyangan, focusing on ninth-grade students who were learning the topic of curved-surface solid geometry.

4. Research Population and Sample

The population of this study consisted of all ninth-grade students at SMP Negeri 1 Paguyangan, which included 11 classes, from IX A to IX K. The sampling in this study was conducted using a **non-probability sampling** method. Non-probability sampling is a technique in which not all members of the population have an equal chance of being selected as part of the sample.

(Sugiyono, 2013). In selecting the sample class, the researcher used a **convenience sampling** technique. This sampling method was chosen based on the ease of access in obtaining the required data. (Golzar et al., 2022). After consultation, two classes were selected as the research samples: class IX H as the **experimental group**, which received treatment using Augmented Reality-based mathematics learning media with **Assemblr Edu**, and class IX G as the **control group**, which received instruction without the use of learning media.

5. Research Instruments

The instruments used in this study were questionnaires and tests, including pretests and posttests. Instrument testing involved both **validity** and **reliability** tests. The validity test was used to assess the accuracy or appropriateness of each item in the instrument. (Malik, 2018). The research instrument, as a measuring tool, needed to be tested for consistency through a

reliability test to ensure that the results produced by the instrument were trustworthy and dependable. (Malik, 2018).

The purpose of this study was to analyze the validity of Augmented Reality-based mathematics learning media using Assemblr Edu on the topic of curved-surface solids for ninth-grade students, and to analyze its effectiveness in improving the mathematical understanding ability of students at SMPN 1 Paguyangan, Brebes Regency. Data were collected through questionnaires and tests. The research instruments included validation sheets assessed by material experts, media experts, mathematics teachers, and student evaluations of product appeal, which were used to determine the validity of the developed media. Meanwhile, the effectiveness of the media was analyzed using the N-Gain test, with interpretation based on the N-Gain interpretation table.

6. Data Analysis Techniques

The data analysis technique is a process that begins with data collection, followed by data preparation, and ends with drawing conclusions. (Sugiyono, 2013). The following are data analysis techniques used to determine the accuracy of decision-making in addressing the research problem formulation.

a. Validity of Learning Media

The table 1 serves as the basis for decision-making in assessing the validity of the media, as evaluated by material experts and media experts, using the criteria below:

Table 1. Expert Validation Criteria

Validity Coefficient	Criteria
$84\% < scores \leq 100\%$	Very Valid
$68\% < scores \leq 84\%$	Valid
$52\% < scores \leq 68\%$	Valid Enough
$36\% < scores \leq 52\%$	Invalid
$20\% \leq scores \leq 36\%$	Very Invalid

Meanwhile, assessments by mathematics teachers and students' evaluations of the product's attractiveness served as supporting factors in determining the validity of the learning media, based on the following criteria:

Table 2. Product Attractiveness Criteria

Achievement Level	Quality of Attractiveness Aspect
$84\% < scores \leq 100\%$	Very Interesting
$68\% < scores \leq 84\%$	Interesting
$52\% < scores \leq 68\%$	Interesting Enough
$36\% < scores \leq 52\%$	Not Interesting
$20\% \leq scores \leq 36\%$	Very Unattractive

Therefore, a product is considered valid if it meets the validity criteria based on expert evaluations and product trial data analysis.

b. Learning Media Effectiveness

After all data were collected, the results were analyzed using the **N-Gain test** to determine the effectiveness of the media in improving the mathematical understanding ability of ninth-grade students. The N-Gain test was applied to assess the relative improvement if there was a significant difference between the average pretest and posttest scores of the experimental class and those of the control class.

$$N - Gain = \frac{post\ test\ score - \ pre\ test\ score}{ideal\ maximum\ score - \ pretest\ score}$$

The classification of normalized *N-Gain* is presented in table 3:

Table 3. *N-Gain* Score Criteria

***N-Gain* Value**	**Category**
$0{,}70 \leq N - gain \leq 1{,}00$	High
$0{,}30 \leq N - gain < 0{,}70$	Medium
$0{,}00 < N - gain < 0{,}30$	Low
$N - gain = 0{,}00$	Stay
$-1{,}00 \leq N - gain < 0{,}00$	There was a Decrease

Furthermore, the data obtained from the N-Gain categories were converted into percentages (%) to evaluate the effectiveness of the Augmented Reality-based mathematics learning media using Assemblr Edu, as shown in the interpretation criteria table below.

Table 4. *N-Gain* Effectiveness Interpretation Categories

Percentage (%)	**Interpretation**
$75 < effectiveness \leq 100$	Effective
$55 < effectiveness \leq 75$	Effective Enough
$40 < effectiveness \leq 55$	Less Effective
$0 < effectiveness \leq 40$	Ineffective

Based on Table 4, the Augmented Reality-based mathematics learning media using **Assemblr Edu** is considered effective if the N-Gain percentage value exceeds 75%.

In addition, a **t-test** was conducted to determine whether there was a significant difference between the two sample groups and to assess whether this difference could be generalized to the larger population. The t-test was performed only after completing prerequisite tests—namely, the **normality test** and **homogeneity test**—to ensure that the data were both valid and homogeneous.

1) Prerequisite Test

a) Normality Test

The normality test was conducted using the **Kolmogorov–Smirnov test** to ensure that the N-Gain data from both sample classes were normally distributed. The criterion used was that the significance value must be **≥ 0.05**. (Nuryadi et al., 2017).

b) Homogeneity Test

The **homogeneity test** was conducted to determine whether the two groups had equal variances. In this study, the test was performed using the **SPSS version 22** software by comparing the N-Gain values of the two classes. Homogeneity was considered to be met if $F_{count} < F_{table}$ at a significant level of 5%.

2) Two Free Samples t-test

Furthermore, after confirming that the data were normally distributed, an **independent samples t-test** was conducted using **SPSS version 22** on the N-Gain scores of the experimental and control classes. Hypothesis testing was carried out at a **5% significance level** to determine the effectiveness of the Augmented Reality-based mathematics learning media developed using **Assemblr Edu**. (Ramadhani & Bina, 2021).

$H_0: \mu_1 = \mu_2$ (There is no significant difference between the average N-Gain scores of the experimental and control classes.)

$H_1: \mu_1 \neq \mu_2$ (There is a significant difference between the average N-Gain scores of the experimental and control classes.)

Where

Where:
μ_1 : Average N-Gain score of students in the experimental class
μ_2 : Average N-Gain score of students in the control class

Decision **Criteria for Hypothesis Testing:**

Hypothesis testing was based on the **p-value** (significance value, Sig.) obtained from the independent samples t-test, with the following criteria:

a) If **Sig. ≤ 0.05**, then **H_0 is rejected** and **H_1 is accepted**.
b) If **Sig. > 0.05**, then **H_0 is accepted** and **H_1 is rejected**.

Therefore, the product is considered **effective** if the N-Gain score of the experimental class is greater than that of the control class, and the significance value (Sig.) from the independent samples t-test is **≤ 0.05**, indicating a statistically significant difference.

C. Research Result and Discussion

1. Research Result

The research and development conducted in this study resulted in a mathematics learning media product focused on curved-surface solid geometry. The media was developed with the aim of improving students' mathematical understanding.

The development process followed the Research and Development (R&D) approach using the ADDIE model—Analysis, Design, Development, Implementation, and Evaluation—which was modified as needed based on the results of the initial analysis.

a. Analysis Stage

The initial stage in developing Augmented Reality-based mathematics learning media is the **analysis** phase, which aims to gather information about the challenges faced by students during the learning process. At this stage, observations were conducted. The results indicated that innovation in mathematics learning for junior high school students, specifically on the topic of curved-surface solids, through the use of Augmented Reality-based media had not yet been implemented. However, such innovation has the potential to increase students' interest in learning and to facilitate their understanding of mathematical concepts.

b. Design Stage

The **design** stage involves the preparation of detailed plans to be applied in the development of the Augmented Reality-based mathematics learning media. In this second phase, the researcher focused on the process of designing the product, which included developing a media framework, determining learning objectives and learning outcomes, organizing the instructional materials, and creating storyboards.

c. Development Stage

The third stage is the **development** phase, which involves transforming the storyboard designs into a functional product. In this study, the development process focused on creating Augmented Reality-based mathematics learning media using Assemblr Edu, with the final output in the form of a QR marker and web link.

Below are several learning displays aligned with the specified learning indicators.

Image 1 . "Definitions" feature related to the First Indicator

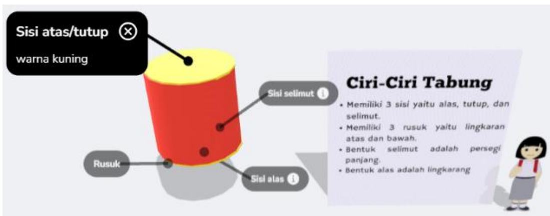

Image 2 . "Traits" feature related to the Second Indicator

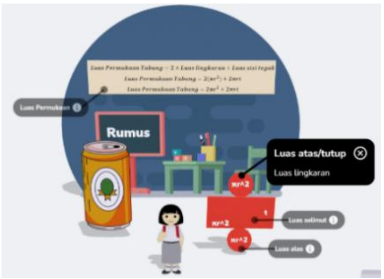

Image 3 . The "Nets" feature related to the Third Indicator

Image 4 . "Surface Area" feature related to the Fourth Indicator

Image 5 . "Volume" feature related to the Fifth Indicator

Image 6 . Results of the developed product

The Augmented Reality-based mathematics learning media developed using **Assemblr Edu** was designed as an effort to improve students' mathematical understanding, enabling them to master five key research indicators. These indicators of mathematical understanding include: (1) restating a concept; (2) classifying objects according to specific properties; (3) representing mathematical concepts in various forms; (4) applying concepts or algorithms in problem-solving; and (5) developing necessary or sufficient conditions for a concept.

Furthermore, the developed learning media was validated by both material experts and media experts. The first validation, conducted by material experts, assessed three aspects: content feasibility, presentation quality, and language use, across 12 statement items. Each aspect received a score of 80%, which meets the criteria for validity (see Table 1). Based on these results, the content of the Augmented Reality-based mathematics learning media on curved-surface solid geometry was deemed suitable for classroom implementation and student testing.

The second validation, conducted by media experts, evaluated the feasibility of the product based on two aspects: physical appearance and presentation and visual communication, using 10 statement items. The results showed that both aspects were categorized as "Very Valid", with scores of 93.3% and 90%, respectively. The average percentage across all aspects of the media expert validation was 91.6%, which also falls within the "Very Valid" category (see Table 1). Thus, it can be concluded that the AR-based mathematics learning media developed using Assemblr Edu is feasible for use and ready for classroom testing.

d. Implementation Stage

In the fourth stage, the development of the learning media entered the **implementation phase**, which included four stages of testing to validate the quality of the media. The specific steps involved in the implementation phase are outlined as follows:

1) Teacher Practicality Test
2) The practicality test consisted of 11 statement items. The results showed that 3 items received a score of 80%, categorized as "Interesting", and 8 items received a score of 100%, categorized as "Very Interesting". Thus, the overall average score was 94.5%, falling into the "Very Interesting" category (see Table 2). Based on these results, the Augmented Reality-based mathematics learning media is considered feasible and suitable for further testing.Small Group Trial
3) The small group trial produced an average score of 80.54%, which is categorized as "Interesting" (see Table 2). Therefore, the Augmented Reality-based mathematics learning media is deemed interesting and can be tested in experimental classes and used as a learning tool.Test Instrument Test

   The test instrument was validated to ensure that the tools used in both experimental and control groups were valid and reliable. The validation involved 30 students from class IX F. The instruments, in the form of pretests and posttests, consisted of five descriptive questions. Items were considered valid if the value of $r_{count} > r_{table}$, and reliable if Cronbach's Alpha > 0.60. Given 30 respondents, the value of **r**$r_{count} > r_{table} = 0.361$. The results showed that values for pretest and posttest items exceeded 0.361. The Cronbach's Alpha values were 0.745 (pretest) and 0.751 (posttest), both > 0.60. Therefore, the test items were declared valid and reliable and appropriate for use in both the control and experimental classes.
4) Field Trial

Field trials were conducted using two sample classes: class IX G as the control group and class IX H as the experimental group. The control class did not receive treatment in the form of Augmented Reality-based mathematics learning media, while the experimental class received the learning media as a treatment. All sample classes were given both a pretest and a posttest to analyze the improvement in mathematical understanding. In addition, all students in the experimental class were asked to complete a questionnaire to evaluate the attractiveness of the Augmented Reality-based learning media. The average percentage score from the product attractiveness questionnaire in the experimental class was 78.48%, which falls under the "Interesting" category (see Table 2). Therefore, the Augmented Reality-based mathematics learning media is considered interesting and suitable for use in learning the topic of curved-surface solid geometry in grade IX. Subsequently, the statistical data for the pretest and posttest results of the control class, consisting of 30 students, are presented in Table 5.

Table 5. Statistical Data of *Pretest* and *Posttest* Results of Control Class

***Pretest* Statistical Data**		***Posttest* Statistical Data**	
Number of Students	30	Number of Students	30
Highest Score	55	Highest Score	80
Lowest Score	25	Lowest Score	45
Average	31,83	Average	56

Based on Table 5, the average scores for the pretest and posttest in the control class fall within the low and medium categories.

Meanwhile, the statistical data for the pretest and posttest results in the experimental class, which consisted of 30 respondents, are presented in Table 6.

Table 6. Statistical Data of *Pretest* and *Posttest* Results of Experimental Classes

***Pretest* Statistical Data**		***Posttest* Statistical Data**	
Number of Students	30	Number of Students	30
Highest Score	60	Highest Score	75
Lowest Score	20	Lowest Score	95
Average	34,33	Average	85,33

Table 6 shows that the average pretest score for the experimental class was 31.67, which falls into the low category. However, the average posttest score for the same class increased significantly to 85.33, placing it in the very high category.

e. Evaluation Stage

The final stage of the **ADDIE** model is the **evaluation** phase. In this stage, a **summative assessment** was conducted to evaluate both the overall development process and the final product. This study employed two types of tests: the N-Gain test and hypothesis testing.

1) N-Gain Test

The N-Gain test, or Normalized Gain test, is used to measure the improvement in students' abilities during the learning process. This test compares the pretest and posttest scores of both the experimental and control classes to evaluate the effectiveness of the Augmented Reality-based mathematics learning media.

The table below presents the results of the N-Gain test for the control and experimental classes.

Table 7. Statistical Data of N-Gain Results of Control Class and Experimental Classes

Control Class *N-Gain* Results		**Experimental Class *N-Gain* Results**	
Number of Students	30	Number of Students	30
Highest Score	0.71	Highest Score	0.94
Lowest Score	0.21	Lowest Score	0.5
Average	0.357	Average	0.771

The data showed that the average N-Gain score for the control class was 0.357, which falls into the medium category, while the average N-Gain score for the experimental class was 0.771, categorized as high. These scores were then converted into percentages for interpretation to determine the effectiveness of the Augmented Reality-based mathematics learning media. When converted, the average N-Gain score of the control class was 35.7%. Based on the N-Gain interpretation table, this score falls into the "Not Effective" category. This indicates that conventional learning, as applied in the control class without the use of Augmented Reality-based learning media, was not effective in improving students' mathematical understanding. In contrast, the average N-Gain score of the experimental class was 77.1%, which, according to the interpretation table, falls into the "Effective" category. Therefore, it can be concluded that the use of Augmented Reality-based mathematics learning media is effective in enhancing the mathematical understanding of ninth-grade junior high school students.

2) T-test

a) Prerequisite Test

(1) Prerequisite testing is conducted prior to the hypothesis testing process. The data must meet the assumptions of normality and homogeneity to be considered valid for hypothesis testing.Normality Test

The normality test was conducted using the Kolmogorov–Smirnov test to ensure that the N-Gain data from both sample classes were normally distributed. The test was performed using SPSS version 22, with the criterion that the significance value must be ≥ 0.05.

Table 8. Normality Test Results

One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residual
N		60
Normal Parameters[a,b]	Mean	,0000000
	Std. Deviation	,11742265
Most Extreme Differences	Absolute	,097
	Positive	,079
	Negative	-,097
Test Statistic		,097
Asymp. Sig. (2-tailed)		,200[c,d]

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. This is a lower bound of the true significance.

(2) The normality test showed that the Asymp. Sig. (2-tailed) value of the Kolmogorov–Smirnov test was 0.200, which is greater than 0.050. Therefore, H_0 was accepted and H_1 was rejected, indicating that the N-Gain data from both the experimental and control classes were normally distributed.Homogeneity Test

The following table presents the results of the homogeneity test.

Table 9. Homogeneity Test Results

Test of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
n_gain	Based on Mean	,003	1	58	,954
	Based on Median	,001	1	58	,970
	Based on Median and with adjusted df	,001	1	54,387	,970
	Based on trimmed mean	,015	1	58	,904

b) The result of the homogeneity test showed a significance value of 0.954, which was greater than 0.050, indicating that H_0 was accepted and H_1 was rejected. In conclusion, the N-Gain data from both sample classes met the criteria for homogeneity, meaning that the two classes had equal levels of mathematical understanding ability prior to treatment.Two Independent Samples T-test

The t-test was conducted after confirming that the data from both sample classes were normally distributed. This test was performed using SPSS version 22.

The following table presents the results of the independent samples t-test.

Table 10. T-test Results

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
n_gain	Equal variances assumed	,003	,954	-13,334	58	,000	-,41400	,03105	-,47615	-,35185
	Equal variances not assumed			-13,334	57,487	,000	-,41400	,03105	-,47616	-,35184

Based on Table 10, the results of the t-test, specifically in the "Equal variances assumed" row and the "Sig. (2-tailed)" column, show a significance value of 0.000, which was less than 0.05. This indicates that H_0 was rejected and H_1 was accepted, meaning there was a significant difference in the average N-Gain scores between the experimental and control classes.

From the results, the average N-Gain score in the control class was 0.357 (or 35.7%), which falls into the "Moderate" category. Meanwhile, the experimental class achieved an average N-Gain score of 0.771 (or 77.1%), which is categorized as "High."

It can be concluded that the use of Augmented Reality-based mathematics learning media in the experimental class was more effective than conventional methods used in the control class in improving the mathematical understanding ability of ninth-grade students at SMPN 1 Paguyangan.

2. Discussion

a. Validity of Augmented Reality-based Mathematics Learning Media using Assemblr Edu on the Material of Curved Side Spaces in Class IX

The output of *Augmented Reality-based* math learning media using *Assemblr Edu* whose final result is in the form of *QR Markers* and *Web Links*. The level of validity in *Augmented Reality-based* math learning media is obtained based on data from material expert tests, media expert tests, teacher assessments, and student interest questionnaire assessments.

First, the average percentage value of all aspects of the material expert assessment is 80% and is included in the "Valid" criteria. Second, the average percentage value of all assessments of media experts is 91.6% and is included in the "Very Valid" criteria. Third, the practicality test by teachers on the attractiveness sheet consists of 11 statement items and average percentage is 94.5% with criteria of "Very Interesting". Fourth, the results of student attractiveness with the average percentage obtained were 78.48% and met the criteria of "Interesting". Thus, it can be concluded that Augmented Reality-based math learning media is valid as a math learning media on the material of the curved side of class IX.

b. Effectiveness of Augmented Reality-Based Mathematics Learning Media using Assemblr Edu to Improve Mathematical Comprehension Ability of Class IX Students of SMPN 1 Paguyangan Brebes Regency

To determine the effectiveness of *Augmented Reality-based* math learning media, each of the two classes samples was given a *pretest* and *posttest*. The results of these values are used for data on the *N-Gain* test which aims to identify the increase in student scores in learning. Previously, the results of the *N-Gain* value were tested for normality first. This was followed by a homogeneity test which aims to determine the homogeneity of the data. The results obtained showed that data were normally distributed and homogeneous, thus fulfilling the requirements for hypothesis testing.

The average of the control class *N-Gain* results is 0.357 or 35.7% and is included in the "Medium" criteria. Then, the score is interpreted in accordance with the *N-Gain* interpretation table, which means that conventional learning in the control class without using media is not effective in improving students' mathematical understanding skills. Meanwhile, the average *N-Gain* value of the experimental class was 0.771 or 77.1% and was included in the "High" criteria. Furthermore, the interpretation of the score concluded that learning in experimental classes with *Augmented Reality-based* mathematics learning media treatment was effective in improving students mathematical understanding skills.

Furthermore, to ensure that the samples used in this study are representative of the population, a t-test was conducted on two independent samples using the *N-Gain* data. Based on the analysis, the significance value (2-tailed) is '0.000 <0.05, so the hypothesis H_0 is rejected and H_1 is accepted. Thus, it can be concluded that the use of media is more effective than conventional learning. The conclusion of the hypothesis test shows that the use of *Augmented Reality-based* mathematics learning media on the IX grade curved side space material effectively improves students' mathematical understanding ability.

The results of the hypothesis test indicated that the use of Augmented Reality-based mathematics learning media on curved-surface solid figures for Grade IX was effective in improving students' mathematical understanding. This finding is supported by observations from the learning process conducted over three meetings in each sample class. In the control class, a conventional lecture method was applied. The learning session began with greetings, a prayer, and an attendance check. The teacher then reviewed prerequisite material namely, the perimeter and area of flat shapes and proceeded to explain the learning objectives and benefits. During the learning process, students generally remained passive, mostly sitting quietly, listening, and taking notes. Student participation was minimal. While discussing example problems, most students remained silent, with only one or two daring to ask questions. The teacher then assigned practice problems, which students completed individually. Once finished, the class reviewed the answers together at the board. In the final session, the teacher led a brief summary of the material. Again, only one or two students shared their thoughts, while the rest passively listened. The teacher closed the lesson by giving praise and encouragement, followed by an overview of the next topic, and ended with a closing greeting.

In contrast, the experimental class implemented learning using media with a contextual approach. At the first meeting, the class began with a discussion of the definition and properties of curved-surface solid figures. As with typical classroom routines, the session started with greetings, a prayer, and attendance checking. Afterward, the teacher guided students to access the Augmented Reality-based learning media developed using Assemblr Edu. The teacher introduced the features of the media and explained how it would be used in subsequent learning activities.

Learners and educators together start the first learning with the "Definition" feature in which it defines tubes, cones, and spheres as well as differences in surface area and volume related to contextual problems. This allows students to apply the concepts learned in a real context. Learners in the experimental class actively participated in learning such as actively conducting discussion activities with their peers to define and conclude the meaning in their own language.

This is followed by the material on the "Characteristics" feature which classifies properties based on the concept of tubes, cones, and spheres. In this section, all students are invited to observe and classify properties based on 3D concepts contained in the media. From this learning, students also actively ask questions and critically respond to questions from the educator. After students classify the properties, there is one student who conveys the answer. At the end, students can answer practice questions on the "Quiz" feature according to the meeting.

The second meeting in the experimental class studied the material of the net and surface area. Learners and educators together open the first material on the "Net" feature which presents the concept of tubes, cones, and spheres into mathematical representations, namely nets. In this section, students are invited to relate the previously learned properties to the nets. This is followed by the material on the "Surface Area" feature which applies the concepts that have been found based on the nets to solve surface area problems by presenting example problems to be discussed.

The third meeting in the experimental class studied volume material. Learners and educators together open the material on the "Volume" feature in which students develop necessary or sufficient conditions for the concept of volume of tubes, cones, and spheres. In this section, students are invited to understand volume first, then presented with examples of problems that can develop the necessary or sufficient conditions of a concept. And students also actively ask questions and critically respond to questions from educators.

The conclusion that can be drawn based on the explanation of the process in the experimental and control classes is that students in the experimental class are more active than students in the control class. During the learning process, students in the experimental class showed active participation by developing ideas, asking questions, and expressing their opinions. Especially the learning media was accompanied by contextual questions that allowed students to apply the material to everyday situations.

D. Conclusion

The results of this research, answering the formulation of problem which is summarized in the conclusion, namely: *Augmented Reality-based* math learning media using *Assemblr Edu* has been validated and declared valid by material experts with a percentage of 80% into the "Valid" category and media expert validation with a percentage of 91.6% into the "Very Valid" category. In addition, the results of practicality test by teachers also showed that this product was very interesting with a percentage of 94.5% in the "Very Interesting". Meanwhile, the results of the product attractiveness questionnaire from the experimental group obtained a percentage of 78.48% with the category "Interesting". From the results of the analysis that

Augmented Reality-based mathematics learning media using *Assemblr Edu* is valid and interesting to be used in learning mathematics curved side space building materials.

Augmented Reality-based mathematics learning media using *Assemblr Edu* proved to be effective in optimizing students mathematical understanding skills by using the maximum limit of the 0.050 significance level showing the average value of *N-Gain* score of 0.771 in the experimental class which is as "High", better than the average *N-Gain* score of 0.357 in the control class which is categorized as "Medium". Based on the independent samples t-test, the results indicate a significant difference between the average mathematical understanding abilities of students in the control and experimental classes. The significance value (Sig. 2-tailed) was 0.000, which is less than 0.050, indicating that the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted.This research shows that AR-based interactive visualization significantly improves students' understanding of spatial geometry concepts through the manipulation of virtual 3D objects. The implications of these findings are promising for application to other math topics. For example, in algebra, the concept of function can be visualized as a 3D graph that students can explore from multiple viewpoints, allowing for a more intuitive understanding of how changes in parameters affect the shape of the graph. Furthermore, in the topic of calculus, the concept of Riemann integral can be brought to life by displaying an approximation of the area under the curve through a number of progressively decreasing rectangles, providing a dynamic visual representation of the limit process. By utilizing the advantages of AR in presenting interactive and immersive visual representations, we can design learning tools that not only make abstract mathematical concepts more concrete, but also encourage active exploration and deep understanding for students in various branches of mathematics.

From a scientific point of view, this study contributes to a deeper understanding of the effectiveness of Augmented Reality (AR) technology as an innovation in mathematics education. The findings of this study enrich the existing literature by providing empirical evidence on how interactive visualization and manipulation of virtual objects in AR environments can influence students' cognitive processes in understanding abstract mathematical concepts.

Pedagogically, this research offers significant contributions in designing learning experiences that are more engaging, relevant, and personalized for students. The AR learning media developed has the potential to overcome students' difficulties in visualizing mathematical concepts, facilitate active and discovery-based learning, and increase students' motivation and involvement in the learning process. Thus, this research provides practical insights for educators and curriculum developers in integrating AR technology as an effective tool to improve students' mathematical understanding at various levels of education.

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An Analysis of Students' Mathematical Problem-Solving Ability in Relation to Their Mathematical Anxiety: A Study of Grade VII Students at SMP Muhammadiyah Sokaraja

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Abstract: This study aimed to analyze the mathematical problem-solving abilities of seventh-grade students at SMP Muhammadiyah Sokaraja in relation to the mathematical anxiety they experienced. This research was conducted as qualitative field research, with data collected at SMP Muhammadiyah Sokaraja. The subjects of the study were students from Class VII B. Data were obtained through observation, interviews, and problem-solving tests. The tests were administered to assess students' mathematical problem-solving abilities, which were then categorized into three levels: low, moderate, and high. Students were subsequently observed and interviewed regarding their experiences of mathematical anxiety. These observations and interviews were conducted over three meetings. The findings revealed that students with low problem-solving abilities tended to experience mathematical anxiety in the form of difficulty speaking or trembling voices, dependence on peers, frequent help-seeking, dislike of mathematics, and heart palpitations. Students in the moderate category exhibited anxiety such as dizziness, heart palpitations, and fear of failure. Meanwhile, students in the high category of mathematical problem-solving ability tended to experience anxiety only in the form of worry or fear of failure.

Keywords: mathematical problem-solving ability; anxiety; math anxiety

A. Introduction

Education is one way that can change the attitudes and behavior of individuals or groups of individuals in an effort to help them develop as human beings. Education plays a very important role in human life. Everything that affects a person's condition, growth, and transformation is influenced by education (Pristiwanti et al., 2022). Through education, a person acquires important skills needed in the world of work, which helps in fulfilling professional growth.

Mathematics is one of the subjects in formal education. In the Great Dictionary of the Indonesian Language, mathematics is the science of numbers and everything related to them which includes all kinds of operational strategies used in solving problems about numbers (Sugiyamti, 2018). This subject is one of the subjects that is often considered difficult by students. Mathematics is a subject that is obtained from elementary school to high school or equivalent. Learning mathematics can encourage students to think logically, critically, and systematically, which requires quite high focus and concentration. The objectives of learning mathematics in the Independent Curriculum include deep conceptual understanding, problem-solving skills, and the application of mathematics in the real world (Solehah & Setiawan, 2023). Therefore, the ability to solve problems is an important aspect that must be mastered by students in learning mathematics, because problem-solving skills are one of the objectives of learning mathematics.

Mathematical problem-solving ability be interpreted as the ability to find a way out of a situation where someone does not know the specific structure by combining various scientific concepts and rules that have been obtained (Novitasari & Wilujeng, 2018). According to Polya, problem solving is an effort to find a way out of a problem in order to achieve a goal that cannot be achieved easily (Purba et al., 2021). To solve the mathematics problem, teachers demonstrated three activities there are seeking to find patterns, creating models for mathematical ideas, and using symbolic representations of ideas (Hailikari et al., 2022). In its application, it is not uncommon for students to have negative assumptions about mathematics, such as considering it difficult in advance, so they hesitate or even do not want to try to solve the problems. This will certainly have an impact on poor mathematical problem-solving abilities and mathematics learning outcomes among students. One of the causes is the excessive anxiety about mathematics subjects experienced by students, which is known as mathematics anxiety.

Anxiety according to Leonard's is a feeling of fear and worry characterized by extraordinary anxiety and tension felt by students during teaching and learning activities (Mukholil, 2018). Mathematics anxiety is an uncomfortable feeling that arises when facing mathematical problems, characterized by fear and worry in certain mathematical situations (Santri, 2017). Anxiety is a form of emotional expression in response to pressure and threats. Someone who experiences mathematical anxiety will consider mathematics as a difficult subject. Anxiety also makes students feel afraid and less confident during the mathematics learning process. Anxiety is one of the factors that hinders students in learning which can interfere with a person's cognitive abilities, such as concentrating, remembering, formulating concepts, and solving problems. Situations like this can result in a decrease in students' mathematics achievement.

Based on the description above, it is known that one of the factors related to students' mathematical problem-solving ability is the mathematical anxiety experienced by students. The anxiety they experience can affect the way students solve mathematical problems. Therefore, this study was conducted with the aim of analyzing mathematical problem-solving ability in terms of mathematical anxiety experienced by students.

B. Methods

This research was conducted using field research with a qualitative approach. Qualitative research is a research method that uses words to describe and explain the meaning of each phenomenon, symptom, or certain social situation (Waruwu, 2023). In this study, the researchers were directly involved in the field and conducted the research objectively.

In this study, the subjects of the study were students of class VII B of SMP Muhammadiyah Sokaraja, which consisted of 31 students. In qualitative research, the research subject or respondent or also called an informant, is someone who can provide information about the research being conducted. The data collection techniques used in this study were tests, observations, and interviews, and the data produced was narrative in nature. The research subjects, namely students of Class VII B, were given a mathematical problem-solving ability test, which was then classified into three categories: low, medium, and high. Subsequently, the students were also observed and interviewed regarding their mathematical anxiety. The researchers conducted observations in the classroom, when mathematics teaching and learning activities were taking place. Observations and interviews were conducted for 3 (three) meetings. After the data was collected, it would be analyzed using data analysis techniques from Miles and Huberman, including data reduction, data presentation, and drawing conclusions (Haryoko et al., 2020). The researchers reduced the data from the results obtained through tests, observations, and interviews with students of class VII B of SMP Muhammadiyah Sokaraja. The research data was then presented in the form of narrative text, which could be in the form of field notes, matrices, charts, diagrams, or the like. After the data was presented, the researcher could draw conclusions regarding the formulation of the problem in this study.

This study also employed a data validity test. The technique used to ensure data validity was **triangulation**.

There are 3 (three) types of data triangulation, namely source triangulation, technique triangulation, and time triangulation (Pratiwi, 2017). In this study, the triangulation techniques used are time triangulation and source triangulation.

C. Results and Discussion

Based on the research that has been conducted, the following results were obtained:

1. Analysis of Students' Mathematical Problem-Solving Ability

Student data from the mathematical problem-solving ability tests were grouped into three categories: low, medium, and high. The grouping of student research subjects refers to table 1.

Table 1. Criteria for Grouping Research Subjects

Grade Criteria (x)	Category
$x < \bar{x} - SD$	Low
$\bar{x} - SD \leq x \leq \bar{x} + SD$	Medium
$x > \bar{x} + SD$	High

The table 2 presents the grouping of students' mathematical problem-solving ability test results.

Table 2. Grouping of Subjects of Mathematical Problem-Solving Ability Test Research

Categori	Grade	Total
Low	$x < 43,1$	8
Medium	$43,1 \leq x \leq 90,5$	18
High	$x > 90,5$	5

Referring to the table 2, the data obtained on students' mathematical problem-solving abilities are 8 (eight) students in the low category, 18 (eighteen) students in the medium category, and 5 (five) students in the high category. The lowest score on this mathematical problem-solving ability test is 25, and the highest score is 100.

2. Analysis of Students' Mathematics Anxiety

The indicators of mathematical anxiety used by researchers in this study are presented in table 3.

Table 3. Mathematics Anxiety Indicators

Number	Math Anxiety Indicators
1.	Sweating
2.	Trembling hands or limbs
3.	Difficulty speaking or trembling voice
4.	Restlessness
5.	Nervousness
6.	Avoiding math class by leaving the class
7.	Dependent on friends or often asking friends
8.	Difficulty concentrating and focusing
9.	Dislike of math lessons
10.	Nausea
11.	Dizziness
12.	Heart palpitations
13.	Suddenly forgetting formulas
14.	Worrying/ fearing of failure

The results of indicator data numbers 1 to 7 were obtained through observation, while indicators numbers 8 to 14 were obtained through interviews. This study was conducted during 3 face-to-face meetings. In the first meeting, the teacher explained the material and conducted a discussion or question and answer session with students. In the second meeting, the teacher continued the previous material accompanied by a discussion session and gave assignments to students. In the third meeting, the teacher reviewed the material that had been discussed previously through discussion and then students were given a test. From the results of observations and interviews in the field, the results were obtained which are presented in the following table.

Table 4. Results of Recapitulation of Students' Mathematics Anxiety Data in the Low Mathematical Problem-Solving Ability Category

Student	Math Anxiety Indicators													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
MHI	×	×	✓	×	×	×	×	×	×	×	×	✓	×	×
	×	✓	✓	×	×	×	✓	×	×	×	✓	×	×	×
	×	✓	×	×	×	×	✓	×	×	×	✓	✓	✓	×
CAY	×	×	×	×	×	×	×	×	✓	×	×	×	×	×
	×	×	×	×	×	×	✓	×	✓	×	×	×	×	×
	×	×	×	×	×	×	✓	×	✓	×	×	×	×	×
KM	×	✓	✓	×	×	×	×	×	×	×	✓	✓	×	×
	×	×	✓	×	×	×	×	✓	✓	×	✓	✓	✓	✓
	×	×	×	×	×	×	×	×	✓	×	✓	✓	✓	✓
ABP	×	×	×	×	×	✓	×	×	×	×	✓	×	×	×
	×	×	×	×	×	✓	×	×	✓	×	✓	✓	✓	✓
	×	×	×	×	✓	✓	×	×	✓	×	✓	✓	×	×
ANA	×	×	✓	×	×	×	✓	×	×	×	×	✓	×	×
	×	×	✓	×	×	×	✓	×	×	×	×	✓	✓	×
	×	×	✓	×	×	×	×	×	×	×	×	✓	×	✓
KNA	×	×	✓	✓	×	×	×	×	✓	×	×	×	×	×
	×	×	×	×	×	×	×	×	✓	×	×	✓	✓	✓
	×	×	✓	×	×	×	×	×	✓	×	×	✓	×	✓
ADM	×	×	✓	×	×	×	✓	×	×	×	×	×	×	×
	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	×	×	✓	×	×	×	✓	×	×	×	✓	×	✓	×
ER	×	×	×	✓	×	×	×	✓	✓	×	×	✓	×	✓
	✓	×	×	✓	✓	×	✓	×	✓	×	×	✓	×	✓
	✓	×	×	✓	✓	×	✓	×	✓	×	×	✓	×	✓

In the first indicator, almost all did not show any anxiety, except ER. Of the eight students, only 1 (one) experienced it, so this first indicator tends not to be experienced by students in the low mathematical problem-solving ability category.

In the second indicator, only MHI and KM showed anxiety in the second indicator. Of the eight students, only 2 (two) experienced it, so this second indicator tends not to be experienced by students with low mathematical problem-solving abilities.

In the third indicator, there were 5 (five) students who showed the presence of mathematical anxiety indicator number three. Because out of 8 (eight) students, 5 (five) students experienced it, this anxiety indicator number 3 tends to be experienced by students with low mathematical problem-solving abilities.

In the fourth indicator, only KNA and ER showed this anxiety. Of the eight students, only 2 (students) experienced this anxiety indicator. So, this fourth indicator tends not to be experienced by students with low mathematical problem-solving abilities.

In the fifth indicator, only ABP and ER showed this anxiety. Of the eight students, only 2 (two) experienced it. So, this fifth indicator tends not to be experienced by students with low mathematical problem-solving abilities.

In the sixth indicator, almost all students did not show this anxiety, only ABP experienced the sixth mathematical anxiety indicator. Because of the eight students, only 1 (one) experienced this anxiety, then this sixth indicator tends not to be experienced by students with low mathematical problem-solving abilities.

In the seventh indicator, only three students did not show anxiety number seven. Because there were 5 (five) out of 8 (eight) students who experienced this anxiety, then this indicator number seven tends to be experienced by students with low mathematical problem-solving abilities.

In the eighth indicator, there were only 2 (two) students, namely KM and ER, who experienced this anxiety. Because only 2 (two) out of 8 (eight) students experienced it, then this eighth mathematical anxiety indicator tends not to be experienced by students with low mathematical problem-solving abilities.

In the ninth indicator, there were 5 (five) out of 8 (eight) students who experienced this mathematical anxiety. Therefore, this indicator of mathematical anxiety tends to be experienced by students with low mathematical problem-solving abilities.

In the tenth indicator, none of the students experienced mathematical anxiety number ten. So students with low mathematical problem-solving abilities do not experience this anxiety indicator.

In the eleventh indicator, there were 4 (four) students who experienced this anxiety. Because there are 8 (eight) students in the low mathematical problem-solving ability category, then this mathematical anxiety indicator is considered balanced, 4 (four) students experienced it and 4 (four) students did not experience it.

In the twelfth indicator, almost all students experienced this mathematical anxiety indicator, namely 6 (six) students who experienced it. 6 (six) out of 8 (eight) students experienced this anxiety, so in this indicator students with low mathematical problem-solving abilities tend to experience the mathematical anxiety indicator number twelve.

In the thirteenth indicator, there were 6 (six) students who experienced this mathematical anxiety. Therefore, the math anxiety indicator number thirteen tends to be experienced by students with low mathematical problem-solving abilities.

In the fourteenth indicator, there are 5 (five) out of 8 (eight) students who experience anxiety indicator number fourteen. Therefore, this math anxiety indicator tends to be experienced by students with low mathematical problem-solving abilities.

Table 5. Results of Recapitulation of Students' Mathematics Anxiety Data in the Moderate Mathematical Problem-Solving Ability Category

Student	Math Anxiety Indicators													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
GNS	×	×	×	×	×	×	×	✓	×	×	×	×	×	×
	×	×	×	×	×	×	×	×	✓	×	×	×	×	✓
	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓
DFA	×	×	×	×	×	×	×	×	×	×	✓	×	×	×
	×	×	×	×	×	×	×	✓	×	×	×	✓	×	✓
	×	×	✓	×	×	×	×	×	×	×	✓	✓	×	✓
SSK	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	×	✓	✓	×	×	×	×	×	✓	×	✓	×	×	×
	×	✓	✓	×	×	×	×	×	×	×	✓	×	×	×
ZP	×	×	×	×	×	×	×	✓	×	×	✓	✓	×	✓
	×	×	×	×	×	×	✓	×	✓	×	✓	×	×	✓
	×	×	×	×	×	×	✓	×	×	×	✓	✓	×	×
AE	×	×	×	×	✓	×	×	×	×	×	×	×	×	×
	×	×	×	×	×	×	×	×	×	×	×	✓	×	✓
	×	✓	×	×	×	×	×	×	×	×	×	✓	×	✓
LF	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	×	×	×	×	×	×	×	×	×	×	×	×	×	✓
	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓
AS	×	×	×	×	×	×	×	✓	✓	✓	✓	×	×	×
	✓	×	×	×	×	×	✓	✓	✓	×	✓	×	✓	✓
	×	×	×	×	×	×	×	×	✓	✓	✓	×	×	✓
RKA	×	×	×	×	×	×	×	×	×	×	✓	✓	×	×
	×	×	×	×	✓	×	×	×	×	×	×	✓	×	×
	×	×	×	✓	×	×	×	×	×	×	✓	✓	✓	×
SHA	×	×	×	×	×	×	×	×	✓	×	✓	×	×	×
	×	×	×	×	×	×	✓	×	✓	×	✓	×	×	×
	×	×	×	×	×	×	×	×	✓	×	✓	×	×	×
AM	×	×	×	×	×	×	×	×	✓	×	✓	×	×	×
	×	×	×	×	×	×	✓	×	✓	×	✓	✓	×	×
	×	×	×	×	×	×	×	×	✓	×	✓	✓	×	×
RNA	×	×	×	×	×	×	×	×	×	×	×	✓	×	×
	×	×	×	×	×	×	×	×	×	×	×	×	×	✓
	×	×	×	×	×	×	×	×	×	×	×	✓	×	✓
FNA	×	×	✓	×	×	×	×	✓	✓	×	×	✓	×	×
	✓	×	✓	×	×	×	✓	×	✓	×	✓	×	×	×
	✓	×	×	×	×	×	×	×	✓	×	✓	✓	×	×
IA	×	×	✓	×	✓	×	×	×	✓	×	✓	✓	×	×
	×	×	×	×	×	×	✓	×	✓	×	✓	✓	✓	✓
	✓	×	✓	×	✓	×	×	×	✓	×	✓	✓	×	✓
DSK	×	×	✓	×	✓	×	×	×	×	×	×	✓	×	×
	×	×	×	×	×	×	×	×	×	×	×	✓	×	×
	×	×	×	×	×	×	×	×	✓	×	×	✓	×	×
WH	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	×	×	×	×	×	×	✓	×	×	×	×	×	✓	×
PN	×	×	×	✓	×	×	×	×	×	×	×	✓	×	×
	×	×	×	✓	×	×	×	×	×	×	✓	×	×	×
	×	×	×	✓	×	×	×	×	×	×	✓	✓	×	✓
IM	×	×	×	×	×	×	×	×	×	×	×	×	×	×

	×	×	×	×	×	×	×	×	✓	×	×	×	×	✓
	×	×	×	×	×	×	✓	×	×	×	×	×	✓	✓
NBR	×	×	×	×	×	×	×	✓	×	×	✓	×	×	✓
	×	×	×	×	×	×	×	×	×	×	×	×	×	✓
	×	×	×	×	×	×	×	✓	×	×	×	×	×	✓

In the first indicator, almost all did not show any anxiety, except AS, FNA, and IA. Of the eighteen students, only 3 (one) showed any anxiety, so in this first indicator it tends not to be experienced by students with moderate mathematical problem-solving ability categories.

In the second indicator, almost all also did not show any mathematical anxiety, except SSK and AE. Because 2 (two) of the 18 (eighteen) students experienced this anxiety, then in this second mathematical anxiety indicator, it tends not to be experienced by students with moderate mathematical problem-solving ability categories.

In the third indicator, there were several students who showed this anxiety, including DFA, SSK, FNA, and IA. Because there were 4 (four) of the 18 (eighteen) students who showed mathematical anxiety indicator number three, then students with moderate mathematical problem-solving ability tend not to experience this mathematical anxiety.

In the fourth indicator, almost all did not show this mathematical anxiety, except RKA and PN. Because out of 18 (eighteen) students only 2 (two) experienced it, then this math anxiety tends not to be experienced by students with moderate mathematical problem-solving abilities.

In the fifth indicator, there are 4 (four) out of 18 (eighteen) students who show this anxiety indicator, including AE, RKA, IA, and DSK. Therefore, this math anxiety tends not to be experienced by students with moderate mathematical problem-solving abilities.

In the sixth indicator, out of 18 (eighteen) students, not a single student showed anxiety in the anxiety indicator number six. Therefore, this math anxiety is not experienced by students with moderate mathematical problem-solving abilities.

In the seventh indicator, there are several students who show this math anxiety indicator, including ZP, AS, SHA, AM, FNA, IA, WH, and IM. Because there are 8 (eight) out of 18 (eighteen) students who show this anxiety, then this anxiety tends not to be experienced by students with moderate mathematical problem-solving abilities.

In the eighth indicator, there are 6 (six) students who experience this anxiety, including GNS, DFA, ZP, AS, FNA, and NBR. Because there are 6 (six) out of 18 (eighteen) students who experience this, then the eighth indicator of mathematical anxiety tends not to be experienced by students with moderate mathematical problem-solving abilities.

In the ninth indicator, there are 10 (ten) students who experience this mathematical anxiety. Because 10 (ten) out of 18 (eighteen) students experience it, this shows that the ninth mathematical anxiety tends to be experienced by students with moderate mathematical problem-solving abilities.

In the tenth indicator, almost all students do not experience this mathematical anxiety. Out of 18 (eighteen) students, only 1 (one) student experiences it, namely AS. So, this tenth mathematical anxiety tends not to be experienced by students with moderate mathematical problem-solving abilities.

In the eleventh indicator, there are 11 (eleven) students out of 18 (eighteen) students who experience this anxiety. This shows that students with moderate mathematical problem-solving abilities tend to experience anxiety indicator number eleven.

In the twelfth indicator, there are also 11 (eleven) students out of 18 (eighteen) students who experience this anxiety. This also shows that the math anxiety indicator number eleven tends to be experienced by students with moderate mathematical problem-solving ability categories.

In the thirteenth indicator, there are several students who experience this anxiety, including GNS, LF, AS, RKA, IA, WH, and IM. Of the 18 (eighteen) students, 7 (seven) of them experience this anxiety. This shows that this math anxiety indicator tends not to be experienced by students with moderate mathematical problem-solving ability categories.

In the fourteenth indicator, there are 11 (eleven) out of 18 (eighteen) students who experience this anxiety. This shows that the math anxiety indicator number fourteen tends to be experienced by students with moderate mathematical problem-solving ability categories.

Table 6. Results of Recapitulation of Students' Mathematics Anxiety Data in the High Mathematical Problem-Solving Ability Category

Student	**Math Anxiety Indicators**													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
RF	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	×	×	×	×	×	×	×	×	×	×	✓	×	×	✓
	×	×	×	×	×	×	×	×	×	×	✓	×	×	✓
RP	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	×	×	×	×	×	×	×	×	×	×	×	×	×	✓
	✓	×	×	×	×	×	×	×	×	×	×	×	×	✓
AN	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	×	×	×	×	×	×	×	×	×	×	×	×	×	✓
	×	×	×	×	×	×	×	×	×	×	×	×	×	✓
NA	×	×	×	×	×	×	×	×	×	×	×	✓	×	✓
	×	×	×	×	×	×	×	×	×	×	×	×	×	✓
	×	×	×	×	×	×	×	×	×	×	×	✓	×	✓
MK	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	×	×	×	×	×	×	×	×	×	×	×	×	×	✓
	×	×	×	×	×	×	×	×	×	×	×	×	×	✓

In the first indicator, out of the five students, almost none showed any mathematical anxiety, except for RP. This shows that the first mathematical anxiety tends not to be experienced by students with high mathematical problem-solving abilities.

In the second indicator, out of the five students who have high category mathematical problem-solving abilities, none of the students showed any anxiety. This means that this second mathematical anxiety indicator is not experienced by students with high mathematical problem-solving abilities.

In the third indicator, out of the five students who have high category mathematical problem-solving abilities, none of the students showed any anxiety. This means that this third mathematical anxiety indicator is not experienced by students with high mathematical problem-solving abilities.

In the fourth indicator, out of the five students who have high category mathematical problem-solving abilities, none of the students showed any anxiety. This means that this fourth mathematical anxiety indicator is not experienced by students with high mathematical problem-solving abilities.

In the fifth indicator, out of the five students who have high category mathematical problem-solving abilities, none of the students showed any anxiety. This means that students with high mathematical problem-solving ability do not experience the fifth indicator of mathematical anxiety.

In the sixth indicator, none of the five students with high mathematical problem-solving ability showed this mathematical anxiety. This means that the sixth indicator of mathematical anxiety is not experienced by students with high mathematical problem-solving ability.

In the seventh indicator, none of the students showed this anxiety. Because none of the five students experienced it, this shows that this indicator of mathematical anxiety is not experienced by students with high mathematical problem-solving ability.

In the eighth indicator, none of the five students who have high category mathematical problem-solving ability, none of the students experienced this anxiety. This means that students with high mathematical problem-solving ability do not experience the eighth indicator of mathematical anxiety.

In the ninth indicator, none of the five students experienced this mathematical anxiety. This shows that this mathematical anxiety is not experienced by students with high mathematical problem-solving ability.

In the tenth indicator, none of the five students experienced this mathematical anxiety. This shows that this tenth math anxiety is not experienced by students with high mathematical problem-solving abilities.

In the eleventh indicator, almost all students do not experience this math anxiety, except RF. Because out of five students, only 1 (one) experiences it, this math anxiety indicator tends not to be experienced by students with high mathematical problem-solving abilities.

In the twelfth indicator, almost all students do not experience this math anxiety, except NA. Out of 5 (five) students, only 1 (one) experiences it, this shows that this math anxiety indicator tends not to be experienced by students with high mathematical problem-solving abilities.

In the thirteenth indicator, none of the 5 (five) students experience this math anxiety. This shows that the math anxiety indicator number thirteen is not experienced by students who have high mathematical problem-solving abilities.

In the fourteenth indicator, there are 5 (five) students out of 5 (five) students who experience this math anxiety. This shows that the math anxiety indicator number fourteen is experienced by all students who have high mathematical problem-solving abilities.

From the research data above, the validity of the data was then tested using triangulation techniques. The triangulation techniques used by researchers are time triangulation and source triangulation. Through the validity test of the time and source triangulation data, the following results were obtained.

Table 7. Results of Mathematics Anxiety Findings Based on Students' Mathematical Problem-Solving Ability Categories

Students with Low Mathematical Problem-Solving Ability (8 students)	**Students with Medium Mathematical Problem-Solving Ability (18 students)**	**Students with High Mathematical Problem-Solving Ability (5 students)**
Difficulty speaking or trembling voice (5 out of 8 students)	Dizziness (10 out of 18 students)	Worrying/ fearing of failure (5 out of 5 students)
Dependent on friends or often asking friends (5 out of 8 students)	Heart palpitations (10 out of 18 students)	
Dislike of math lessons (5 out of 8 students)	Worrying/ fearing of failure (10 out of 18 students)	
Heart palpitations (6 out of 8 students)		

Based on the findings above, it was found that students who have low mathematical problem-solving abilities tend to experience mathematical anxiety in the form of difficulty speaking or a trembling voice, depending on friends or often asking friends, not enjoying mathematics lessons, and a pounding heart. Not enjoying a subject means that students cannot enjoy a subject due to lack of interest and negative assumptions about the subject, so that students will tend to have a shallow understanding and cannot apply it to a problem. This can also cause fear in students which makes it difficult to find solutions to the problems faced, making students not confident and preferring to see friends' answers (Sulistianingsih et al., 2024).

The findings above also explain that students with low mathematical problem-solving abilities, the mathematical anxiety experienced is not only in the physiological aspect, but also in the affective and cognitive aspects. As stated by Suharyadi, mathematical anxiety is divided into 3 (three) aspects, namely cognitive, affective, and physiological (Rizki et al., 2019). Research conducted by Zatul Himmi states that students who meet all indicators of anxiety (affective, cognitive, and physiological) are included in the high level (Himmi, 2022). This is supported by research from Baromea Kameubun, et al., which states that students with high anxiety tend to have difficulty in understanding problems, making solution plans, applying them to problems, and re-checking. This shows the poor mathematical problem-solving abilities of students (Kameubun et al., 2023). Supported by research from Makis Setiawan, Emi Pujiastuti, and Bambang Eko Susilo which states that the level of mathematical anxiety is high, the problem-solving ability is low, and vice versa (Setiawan et al., 2021).

Students who have moderate mathematical problem-solving abilities tend to experience mathematical anxiety in the form of dizziness, heart palpitations, and worry/fear of failure. This shows that students who have moderate mathematical problem-solving abilities are included in mathematical anxiety in the cognitive and physiological aspects. Students with moderate mathematical problem-solving abilities do not show mathematical anxiety in the affective aspect. Affective abilities are closely related to a person's attitudes and interests which are expressed in the form of responsibility, discipline, self-confidence, and self-control (Ulfah & Opan Arifudin, 2021). The affective abilities that are still possessed by students with moderate problem-solving abilities are what make them better than students who meet all anxiety indicators (cognitive, affective, and physiological).

Students who have high mathematical problem-solving abilities only tend to have a sense of worry or fear of failing in mathematics. Physiological indicators of mathematical anxiety such as sweating, heart palpitations, trembling, or nausea are not experienced. This can make students stay calm and focused in dealing with mathematics. According to research conducted by Suherni, et al., calm people can handle stress and difficulties with a good outlook and strong feelings of optimism (Suherni et al., 2024). This means that their ability to be calm and focused is one of the reasons for having higher grades because their mathematical problem-solving abilities are high. This is in line with research conducted by Putri Diana, Indiana Marethi, and Aan Subhan Pamungkas which states that students who show a calm and concentrated attitude get higher grades than students who show excessive anxiety reactions (Diana et al., 2020). Students with a high mathematical problem-solving ability category only experience fear of failure or worry in mathematics lessons, indicating that students with high mathematical problem-solving abilities have low mathematical anxiety. This is supported by research from Baromea Kameubun, et al., which states that students with low mathematics anxiety show better mathematical problem-solving abilities in all indicators of problem-solving abilities (Kameubun et al., 2023).

D. Conclusion

Referring to the results and discussions obtained, the findings in this study indicate that students with low mathematical problem-solving ability tend to experience mathematical anxiety in the form of difficulty speaking or trembling voices, depending on friends or often asking friends, not liking mathematics lessons, and heart palpitations. Then students with moderate mathematical problem-solving ability tend to experience mathematical anxiety in the form of dizziness, heart palpitations, and worry or fear of failure. While students with high mathematical problem-solving ability tend to only experience mathematical anxiety in the form of worry or fear of failure. Based on the results of the study obtained, it can also be concluded regarding the pattern of mathematical anxiety that occurs in grade VII students of SMP Muhammadiyah Sokaraja, namely if students are faced with mathematical problems in the form of questions and answers, assignments, or tests, the mathematical anxiety experienced by students will increase.

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Artificial Intelligence in Mathematics Education: Trends, Challenges, and Opportunities

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Abstract: This paper examines the transformative influence of artificial intelligence (AI) on mathematics education. It delineates the evolution of educational technology, progressing from basic computational tools to advanced AI-driven systems that enhance personalised learning experiences. The study highlights how AI adapt to individual student needs, increase engagement, and promote deeper understanding of mathematical concepts by analysing contemporary trends such as intelligent tutoring systems, automated assessments, and personalised learning platforms. Additionally, it explores the potential of AI to foster inclusive learning environments, particularly for students with special needs. The paper also considers challenges related to infrastructure, teacher preparedness, and equity in AI implementation, alongside future directions for research and innovation in the application of AI within mathematics education.

Keywords: artificial intelligence; mathematic education; personalised learning; educational technology

A. Introduction

Since the mid-1970s, technological advancements have transformed mathematics education. Initially, innovations focused on computational efficiency; however, modern tools now enhance representation, communication, and interactivity (Kaput et al., 2020). Software like Mathematica and Maple engage with traditional notation, enabling symbolic manipulation, iterative computations, and dynamic visualisations (e.g., coordinate graphs and geometric figures) (Lavidas et al., 2022). These tools help students comprehend mathematical concepts. Moreover, advancements in human-computer interaction, especially direct manipulation interfaces, have improved learning through interactive simulations (Beaudouin-Lafon et al., 2021). Despite these changes, core mathematical concepts taught have remained constant (Engelbrecht & Borba, 2024). Technology has also reshaped communication in mathematics education. The Internet and World Wide Web greatly enhance access to mathematical knowledge, changing how students search for solutions. More learners rely on search engines instead of traditional problem-solving methods (Kaput et al., 2020).

In recent years, the emergence of artificial intelligence (AI) has been recognised as a transformative force in the field of mathematics education. According to the research conducted by Opesemowo and Adewuyi (2024), various AI technologies, including prominent tools such as ChatGPT, are progressively being utilised to provide personalised support, facilitate real-time assessments, and generate interactive mathematical explanations. These innovative tools have demonstrated considerable promise in enhancing student engagement and performance, particularly in subjects such as geometry. AI-powered instructional tools markedly enrich digital learning environments by systematically analysing student behaviour, delivering real-time feedback, and customising instruction to meet the distinct learning needs of individual students. Moreover, artificial intelligence is playing a pivotal role in curriculum development and the empowerment of educators. Educators are leveraging AI technologies to identify gaps within the curriculum and tailor instructional methodologies to better meet students' specific needs (Rasheed et.al, 2023; Opesemowo & Adewuyi, 2024). This strategic approach serves to cultivate more responsive and inclusive learning environments. Also, their findings underscore the importance of integrating qualitative and quantitative research methodologies concerning the use of AI, as this combination provides a richer understanding of its effectiveness and pedagogical implications. The pace at which technological integration into mathematics education has unfolded has significantly accelerated in the wake of the COVID-19 pandemic (Vegas & Winthrop, 2020). The pandemic necessitated a widespread transition to online learning (Engelbrecht & Borba, 2024; Wong et al., 2025). This rapid shift has encouraged active learning and increased flexibility and sparked innovation in instructional design. As AI tools continue to evolve and become more sophisticated, their role within mathematics education is anticipated to expand further, enhancing personalisation and interactivity, facilitating collaborative learning, and aiding in teacher decision-making processes.

This paper examines the current trends, challenges and opportunities within AI in Mathematics education. By analysing how AI can be effectively integrated into teaching practices and exploring its implications for curriculum development, this study seeks to provide insights into creating inclusive and adaptive learning environments that cater to the diverse needs of all students. Also, this paper aims to contribute to a deeper understanding of how AI can be harnessed to transform mathematics education.

B. Current trends in AI for Mathematics Education

1. AI-Powered Tutoring Systems

AI is revolutionising mathematics education through Intelligent Tutoring Systems (ITSs), which provide personalised and adaptive instruction. These systems analyze students' psychological states—motivation, emotion, and cognition—along with their prior knowledge, skills, and learning preferences to tailor instruction effectively (Lin et al., 2023). This holistic approach addresses cognitive aspects and considers emotional and motivational factors, thereby fostering a more supportive learning environment.

A key innovation in AI-driven tutoring is adaptive learning, which customises educational experiences to individual needs. By continuously monitoring student progress, ITSs deliver real-time feedback, hints, and scaffolding while dynamically selecting appropriate problems for practice. This approach facilitates the identification of students' strengths and weaknesses, ensuring an optimised learning path for each learner (Lin et al., 2023; Zuo et al., 2023). Features such as adaptive difficulty levels, personalised feedback, and intelligent hints render AI-powered tutoring highly responsive to individual learning needs, closely mirroring one-on-one human tutoring. Such personalisation has been shown to have a significant positive impact on student achievement in mathematics (Yi et al., 2023; Zuo et al, 2023).

Beyond cognitive adaptation, AI enhances engagement by integrating student interests into learning tasks. Research demonstrates that students with a strong personal interest in a subject engage more frequently and independently (Renninger & Pozos-Brewer, 2015). AI can leverage this by embedding mathematical problems within familiar contexts, such as sports, music, or gaming, thereby making abstract concepts more relatable and fostering persistence in problem-solving (Walkington & Bernacki, 2019). Furthermore, by incorporating gamification elements, such as rewards and challenges, AI systems can motivate students to tackle complex mathematical problems with increased enthusiasm (Fuentes-Riffo et al., 2023).

AI can also stimulate situational interest, wherein engagement is triggered by immediate environmental factors (Hidi & Renninger, 2006). ITSs can render learning more visually stimulating, interactive, and relevant to a student's hobbies or aspirations. For instance, interactive simulations and dynamic visualisations can aid students in grasping challenging concepts like calculus or geometry, thereby transforming abstract ideas into tangible experiences. Studies indicate that such personalised approaches enhance enjoyment, attention, and motivation, leading to improved learning outcomes (Høgheim & Reber, 2015; Bernacki & Walkington, 2018).

Moreover, AI research continues to concentrate on modelling learner characteristics by utilising data from diverse sources to construct engaging and adaptive learning experiences (Maghsudi et al., 2021; Rasheed et al., 2023; Santos et al., 2016). This encompasses incorporating learning analytics to monitor student performance over time, enabling educators to make informed decisions about instructional strategies and interventions. Recognising students' diverse experiences, goals, and backgrounds through personalisation and individualised pathways is increasingly acknowledged as a crucial aspect of AI-driven education (Roll & Wylie, 2016). Also, the potential for AI to facilitate collaborative learning experiences should not be overlooked. By connecting students with peers possessing complementary skills or interests, ITSs can promote collaborative problem-solving and social interaction, which are essential components of effective mathematics education (Lopez-Caudana et al., 2020). Thus, AI supports individualised learning and fosters a community of learners who can share knowledge and strategies, ultimately enriching the educational experience (Walter, 2024).

In summary, AI-powered tutoring systems significantly advance mathematics education, offering personalised, engaging, and adaptive learning experiences that address students' diverse needs. As these technologies continue to evolve, their potential to transform mathematics education will only expand, making it imperative for educators and researchers to explore their implications further.

2. Automated assessment and feedback

AI has swiftly established itself as a transformative instrument in the automation of student work assessments, presenting substantial potential to improve both the promptness and quality of the feedback provided to students (Kooli & Yusuf, 2025). Traditional assessment methods, including multiple-choice or closed-ended questions, yield definitive answers that automated systems can efficiently grade. However, open-ended questions, particularly in disciplines such as mathematics, pose a distinct challenge: These problems enable students to exhibit their reasoning, creativity, and problem-solving strategies, yet they are significantly more complex to assess automatically (Botelho et al., 2023). AI, particularly Natural Language Processing (NLP), has the capability to address these challenges by automating the grading and feedback processes for such responses, thereby offering students more comprehensive and meaningful assessments.

Automated systems not only provide rapid feedback on correct or incorrect responses, but they are also increasingly adept at evaluating students' reasoning and problem-solving strategies (Inoferio et al., 2024). Recent NLP and machine learning advancements have considerably enhanced AI's capacity to comprehend and evaluate open-ended responses. For instance, researchers have investigated how AI can assess the quality of student responses by examining the logic and steps involved in problem-solving, rather than merely focusing on the final answer (Botelho et al., 2023). In this context, AI possesses the potential to mimic the function of a human tutor, delivering tailored feedback that addresses not only errors in the final answer but also deficiencies in the student's approach or thought processes (Torres-Peña et al., 2024). Platforms such as ASSISTments and ALEKS™ have demonstrated the advantages of immediate, automated feedback, with studies illustrating that real-time feedback can substantially enhance student learning outcomes (Roschelle et al., 2016). These systems facilitate a more personalised learning experience, aiding students in grasping the underlying concepts and strategies pertinent to their errors.

AI-enhanced assessment tools also promote integrating formative assessment practices within mathematics education (Torres-Peña et al., 2024). By providing continuous feedback rather than relying exclusively on summative assessments, these tools encourage a growth mindset among students. They inspire learners to regard mistakes as opportunities for improvement, ultimately cultivating resilience and persistence in problem-solving (Remoto, 2023). Also, AI systems can generate comprehensive analytics for educators, enabling them to identify specific domains where students encounter difficulties, thereby informing targeted interventions and instructional strategies. The meta-analysis by Yi et al. (2023) showed that AI-based formative assessment systems positively affected student achievement in mathematics, reinforcing the consensus that timely, adaptive feedback improves learning outcomes.

Nevertheless, the complexity of evaluating reasoning and problem-solving continues to present a challenge. In contrast to multiple-choice questions, open-ended questions can elicit an extensive array of responses, complicating AI's ability to uniformly appraise the processes underlying each solution (Botelho et al, 2023). For example, while verifying a correct answer to a mathematical problem is straightforward, comprehending the methodologies a student employed to arrive at that answer necessitates the system to evaluate a multitude of potential strategies, which can vary significantly among students (Gurung & Heffernan, 2022). Moreover, as emphasised by Yi et al. (2023), AI-based assessments frequently grapple with issues of generalizability and fairness, especially when attempting to evaluate reasoning processes that diverge from those represented in the system's training data.

Also, the incorporation of AI in automated assessments can facilitate personalised learning pathways by aligning assessments with each student's learning style and pace (Inoferio et al., 2024; Song et al., 2024). For example, AI can recommend specific practice problems based on previous performance, assisting students in reinforcing weak areas and enhancing their comprehension of advanced concepts. The potential for AI to bolster creative problem-solving is also noteworthy; by analysing diverse approaches to challenges, AI can promote higher-order thinking skills essential for mathematics success.

A paramount barrier to implementing AI-driven assessment for open-ended problems is ensuring fairness and equity. While AI models are increasingly effective at processing complex responses, they may inadvertently perpetuate biases, particularly if trained on data reflecting human biases. For instance, disparities in grading may arise from variations in student effort, prior knowledge, or demographic factors, all of which are typically accounted for by human educators in their assessments (Gurung & Heffernan, 2022). This subjectivity inherent in human grading is difficult to replicate accurately in AI systems. Researchers have explored strategies to mitigate these biases, such as employing anonymised data during the training of AI models to prevent demographic factors from affecting the assessment process (Alali & Wardat, 2024; Gurung & Heffernan, 2022). Such measures are critical to ensuring that AI systems do not reinforce existing inequities in educational assessment.

In summary, AI can revolutionise automated assessments by evaluating the correctness of student responses and offering detailed feedback on the reasoning and problem-solving strategies utilised. By harnessing advancements in NLP and machine learning, AI systems can more effectively assess open-ended questions and provide real-time, personalised feedback to students. However, challenges persist in the automation of creativity assessment and non-standard solutions and in ensuring fairness and equity within AI-driven grading systems. As this field continues to advance, sustained research and development will be imperative to fully actualise the advantages of AI in mathematics education, ultimately enhancing both pedagogical practices and student learning outcomes.

3. Personalised learning platforms

AI-driven personalised learning platforms comprehensively analyse students' learning behaviours, preferences, and performance data to curate content and activities that are meticulously tailored to individual interests and learning styles (Rasheed et al., 2023). These platforms exhibit real-time adaptability, ensuring that each student is provided with appropriate material to their current level of understanding and pace. Such adaptability is particularly crucial in the field of mathematics education, where students frequently progress at varying rates and may require diverse approaches to comprehend complex concepts. Empirical studies have indicated that AI-based personalisation has a statistically significant positive impact on student achievement in mathematics (Wang et al., 2020; Yi et al., 2023).

In particular, tools such as ChatGPT offer students on-demand, personalised support and instant feedback, guiding them through intricate mathematical problems while highlighting areas necessitating additional assistance (Wardat et al., 2023). This individualised methodology significantly aids learners in cultivating confidence in their mathematical skills and promotes heightened engagement (Opesemowo & Adewuyi, 2024). Furthermore, these platforms can identify specific misconceptions and provide targeted interventions, ensuring that students receive the requisite support to overcome obstacles in their educational journey. Additionally, personalised AI platforms are regarded as a pivotal innovation in equipping students with adaptable learning strategies, thus preparing them more effectively for future academic and professional challenges. Engaging with mathematics through practical applications, such as data analysis, coding, and financial literacy, can profoundly enhance students' relevance and interest in the subject matter (Wikaya et al., 2024). According to Awang et al. (2025) and Torres-Peña et al. (2024), adaptive learning platforms like Khan Academy, MathGPT, Squirrel AI, and MathE are widely adopted to deliver personalised instruction throughout primary, secondary, and higher education. These tools dynamically tailor content and feedback based on student progress, rendering them suitable for a spectrum of learning levels and needs. Khan Academy, in particular, distinguishes itself through its global accessibility and incorporation of AI-driven features, including embedded chatbots that elucidate mathematical concepts in real time, emulating a one-on-one tutoring experience. This real-time interaction alleviates queries and fosters a growth mindset, as students can engage with content persistently without the fear of judgment.

Moreover, AI platforms can integrate gamification elements, such as challenges and rewards, to incentivise students and enhance the enjoyment of learning. By transforming mathematical practice into interactive games, these platforms can amplify student engagement and encourage regular practice, which is essential for mastering mathematical concepts. Awang et al. (2025) further explain how commercial AI platforms harness personalization to boost student engagement and performance by providing content tailored to specific mathematical domains, including algebra, geometry, and calculus. Furthermore, using AI in personalised learning can facilitate collaborative learning environments, wherein students may work cooperatively on problem-solving tasks within virtual settings (Wikaya et al., 2024). This social dimension of learning is paramount, reflecting the collaborative essence inherent in many real-world mathematical applications. As students engage in collective discussions and problem-solving activities, they deepen their comprehension and cultivate essential communication and teamwork abilities.

In summary, AI-driven personalised learning platforms signify a substantial advancement in mathematics education, providing tailored experiences that cater to individual needs and learning styles. As these technologies continue to develop, they can transform the methodologies by which mathematics is taught and learned, ultimately culminating in improved outcomes and heightened enthusiasm for the subject among students.

4. AI-assisted curriculum design

AI can systematically analyse vast amounts of student data, thereby identifying critical areas within the curriculum that may exhibit deficiencies or warrant enhancements (Nagaraj et al., 2023; Wijaya et al., 2024). Through the examination of patterns in student performance, behaviour, and engagement levels, AI systems can illuminate specific topics that necessitate greater focus, modifications, or the integration of alternative instructional strategies. This data-driven methodology is a valuable support mechanism for curriculum designers and educators, enabling them to refine educational content to effectively accommodate learners' diverse and dynamic needs (Yi et al., 2023). In cases where a substantial cohort of students struggles with particular mathematical concepts, AI can proactively notify educators of these emerging trends, thereby prompting a detailed review of instructional methods or advocating for the introduction of additional resources tailored to bridge the identified gaps.

Beyond its diagnostic capabilities, AI can also play a pivotal role in developing more effective and engaging learning materials. By leveraging continuous student interaction and feedback mechanisms, AI tools can recommend tailored content adjustments, scaffolded resources, and adaptive activities, all of which are calibrated to meet students' individual needs (Alali & Wardat, 2024; Ezzaim et al., 2023). This adaptive approach ensures that educational materials remain dynamic, relevant, and responsive to students' evolving progress. For instance, AI may propose supplementary exercises for students who exhibit mastery of foundational concepts, while concurrently offering remedial resources for those who require additional support. This focused and targeted strategy is particularly crucial within the field of mathematics education, where a robust understanding of foundational skills is imperative for achieving success in more advanced topics.

Moreover, a growing body of studies has emphasised the transformative potential of AI, not only in augmenting content delivery but also in alleviating the workload on educators by automating routine curriculum development tasks. By streamlining the processes involved in creating assessments, resource materials, and instructional plans, AI enables teachers to redirect their efforts towards more creative and impactful aspects of instruction (Opesemowo & Adewuyi, 2024). This notable shift empowers educators to allocate increased time and resources towards developing engaging pedagogical strategies, fostering a more interactive classroom environment that encourages students' exploration, creativity, and critical thinking.

In summary, integrating AI technology within curriculum design signifies a substantial advancement in mathematics education, equipping educators with the tools necessary to create responsive, engaging, and effective learning experiences.

5. AI for special education needs

AI technologies have the potential to create more inclusive learning environments for students with learning disabilities or other special needs. By personalising instruction and providing adaptive learning experiences, AI can cater to the unique requirements of these students, offering support that aligns with their individual learning profiles (Inoferio et al., 2024). AI-driven platforms can provide real-time feedback, scaffolded instruction, and alternative explanations, helping students overcome barriers to understanding and promoting a sense of autonomy in their learning process (Opesemowo & Adewuyi, 2024). For instance, speech recognition software can assist students with dyslexia by reading text aloud, while interactive visual aids can help those with autism spectrum disorders engage more effectively with mathematical concepts (Mossige et al., 2023). AI can also facilitate collaborative learning opportunities for students with special needs, encouraging peer interaction and support. For instance, AI platforms can pair students with complementary skills, fostering a collaborative environment that benefits both learners. This social aspect of learning is crucial, as it helps students develop their mathematical skills and enhances their social skills and confidence.

In summary, AI technologies hold significant promise for transforming mathematics education, particularly in creating personalised, inclusive, and adaptive learning environments. By leveraging data-driven insights, AI can tailor mathematical instruction to meet the diverse needs of students, including those with learning disabilities and special educational needs. These systems provide real-time feedback on problem-solving strategies, scaffolded resources for concept mastery, and targeted interventions that enhance mathematical understanding and performance.

C. Implications for learning and teaching

Integrating artificial intelligence (AI) into mathematics education presents transformative opportunities for teaching and learning. AI tools, such as ChatGPT, facilitate personalised learning by providing students with instantaneous feedback and scaffolding to assist them in comprehending complex mathematical concepts (Awang et al., 2025; Opesemowo & Adewuyi, 2024). These systems adapt in real-time to accommodate individual student needs, enhancing engagement and improving learning outcomes, particularly in geometry, algebra, and calculus. Intelligent Tutoring Systems (ITSs) exemplify this by continuously monitoring student progress, adjusting difficulty levels, and delivering targeted feedback (Lin et al., 2023), optimising learning pathways tailored to each student's strengths and weaknesses.

Furthermore, AI promotes engagement by contextualising mathematical problems within real-world scenarios that resonate with students' interests, rendering abstract concepts more relatable and fostering persistence in problem-solving (Walkington & Bernacki, 2019). In addition to enriching student experiences, AI serves as a valuable co-instructor for educators by automating routine tasks, including assessment, content recommendation, and data analysis. This automation enables teachers to concentrate on more student-centred instruction (Yi et al., 2023). The capability to provide immediate, personalised feedback, particularly for open-ended questions, facilitates responses that traditional assessment methods often struggle to deliver.

Recent advancements in Natural Language Processing (NLP) empower AI to evaluate correct answers and the reasoning and strategies employed by students (Botelho et al., 2023). This ability facilitates a deeper understanding of errors and enhances problem-solving methodologies. AI tools such as ASSISTments and ALEKS™ demonstrate that real-time feedback can significantly enhance student achievement, particularly when assessments are tailored to individual learning strategies (Roschelle et al., 2016). Moreover, AI supports teachers in refining instruction by identifying performance patterns and recommending targeted interventions (Opesemowo & Adewuyi, 2024). This ensures that curriculum materials remain relevant and responsive to student progress (Yi et al., 2023). Also, AI technologies can foster inclusive learning environments, particularly for students with special needs, by providing personalised support and real-time feedback tailored to their unique learning profiles (Mossige et al., 2023; Opesemowo & Adewuyi, 2024).

However, ensuring that AI tools are equitable and do not introduce biases is imperative, particularly when supporting these students (Yi et al., 2023). Therefore, AI systems must be trained on diverse datasets to prevent the reinforcement of existing disparities in educational opportunities.

In summary, while AI possesses the potential to revolutionise mathematics education by delivering personalised and adaptive learning experiences, careful consideration of fairness, equity, and inclusivity is essential to guarantee equal opportunities for all students. As highlighted by Opesemowo and Adewuyi (2024) and Yi et al. (2023), employing quantitative and qualitative approaches to evaluate AI tools will comprehensively understand their impact on student achievement and the overall educational experience.

D. Challenges and barriers of using AI for Mathematics Education

Despite the potential benefits, several challenges hinder the widespread adoption of AI in mathematics education.

1. Infrastructure and access

Effective implementation of AI tools necessitates robust technological infrastructure and reliable internet access—conditions that are not universally available, particularly in under-resourced schools. Many institutions in disadvantaged areas struggle with outdated hardware and insufficient connectivity, which can severely limit the deployment of AI-driven educational resources (Chalkiadakis et al., 2024; Yi et al., 2023). This disparity affects students' access to personalised learning experiences and exacerbates existing educational inequalities. In mathematics education, where resources like interactive tutorials and real-time feedback are crucial for mastering complex concepts, the lack of adequate infrastructure can impede students' ability to engage fully with the curriculum. Therefore, addressing these infrastructural challenges is essential to ensure equitable access to AI-enhanced mathematics learning tools.

2. Teacher training and readiness

An additional notable obstacle is educators' insufficient training and readiness to effectively integrate artificial intelligence (AI) into mathematics instruction. Numerous educators express feelings of unpreparedness to utilise AI technologies, stemming from inadequate technical abilities or a deficiency in pedagogical understanding regarding the meaningful incorporation of these tools into their teaching methodologies. As Opesemowo and Adewuyi (2024) emphasise, the efficacy of AI in educational settings substantially depends on teachers' preparedness and comfort with digital tools. In the absence of comprehensive professional development programmes that address both the technological and pedagogical dimensions of AI integration, educators may encounter challenges in effectively leveraging these resources to enhance student learning outcomes (Chan & Tang, 2025). This deficiency in readiness can result in inconsistent implementation, wherein AI tools are either underutilised or misaligned with educational objectives, thereby ultimately impeding the potential advantages for students in mathematics education.

3. Bias and equity concerns

Bias and equity concerns represent significant challenges to the integration of artificial intelligence in mathematics education (Cooper & Tang, 2024). There is a risk that AI systems could perpetuate existing biases, particularly in instances where the training data lacks diversity or fails to acknowledge contextual variances (Yi et al., 2023). This dilemma is especially alarming for students with special needs or those from marginalised backgrounds, who may already face systemic barriers within the educational framework. For instance, if an AI tool is predominantly trained on data sourced from high-achieving students, it may not accurately reflect the needs and challenges faced by students who require additional support in mathematics. Such biases can result in a misdiagnosis of learning needs and insufficient assistance for these students, thus further entrenching inequities in educational outcomes. Therefore, it is essential to ensure that AI systems are developed using diverse datasets and are subjected to regular evaluations for fairness to mitigate the exacerbation of existing disparities.

4. Over-reliance on technology

The potential for over-reliance on technology represents a significant concern associated with the integration of artificial intelligence in mathematics education. While artificial intelligence can function as a powerful support tool, there is apprehension that both students and educators may become excessively dependent on automation, thereby diminishing critical thinking and pedagogical intentionality (Atchley et al., 2024; Chen & Lin, 2023). For instance, if students depend exclusively on artificial intelligence for problem-solving, they may forfeit the opportunity to cultivate essential analytical skills and mathematical reasoning. Likewise, educators might unduly rely on artificial intelligence tools for assessment and instruction, potentially neglecting the value of direct student-teacher interactions and personalised feedback. To mitigate this risk, educators must try to balance employing artificial intelligence technologies and upholding traditional pedagogical strategies that encourage a deeper understanding and engagement with mathematical concepts.s.

5. Data privacy and ethics

Ultimately, issues of data privacy and ethical considerations pose considerable challenges regarding the implementation of artificial intelligence in education. The utilisation of AI frequently necessitates the collection and analysis of sensitive student data, raising critical concerns about privacy, consent, and the ethical use of information. Safeguarding data privacy, fostering transparency, and upholding ethical practices remain urgent matters, particularly in instances involving third-party tools (Williams, 2024; Yi et al., 2023). This is especially relevant in the field of mathematics education, where data related to student performance can be sensitive and may impact future opportunities. Educational institutions must navigate the intricacies of data governance while ensuring AI tools adhere to legal and ethical standards. Establishing clear guidelines and policies regarding data usage and privacy is crucial for fostering trust among educators, students, and parents, ensuring that AI enhances the educational experience rather than undermines.

E. Conclusion and Future Directions

In conclusion, the integration of artificial intelligence (AI) into mathematics education presents considerable potential for enhancing teaching and learning experiences. AI can address diverse student needs and increase engagement with intricate mathematical concepts by providing personalised learning pathways, real-time feedback, and adaptive instructional strategies. However, the successful implementation of AI within educational settings depends on overcoming several challenges, including inadequate infrastructure, insufficient teacher training, bias in AI systems, an overreliance on technology, and concerns about data privacy and ethics.

Future directions for mathematics education involving AI should emphasise several key areas. First, it is essential to invest in robust technological infrastructure to ensure equitable access to AI resources across all educational institutions, particularly in under-resourced schools. This includes expanding internet connectivity and providing the necessary hardware to facilitate effective AI integration. Second, comprehensive professional development programs must be established to equip educators with the technical skills and pedagogical knowledge needed for successful AI incorporation. Training should encompass the use of AI tools and the critical evaluation of their effectiveness in meeting diverse student needs. Third, there is a pressing need to address issues of bias and equity within AI systems. This can be achieved by ensuring that AI tools are developed using diverse and representative datasets, alongside routine evaluations to assess their fairness and impact on various student populations. Furthermore, fostering a balanced approach to technology use in classrooms will be crucial. Educators should encourage critical thinking and problem-solving skills by integrating AI as a supportive tool rather than a crutch, ensuring that students remain actively engaged in their learning processes. Lastly, establishing clear guidelines regarding data privacy and ethical considerations surrounding the use of AI will be vital. Schools must ensure that student data is managed transparently and responsibly, fostering trust among all stakeholders.

By addressing these challenges and focusing on these future directions, mathematics education can leverage the full potential of AI, thus creating a more inclusive, effective, and engaging learning environment for all students. This proactive approach will not only enhance mathematical understanding but also adequately prepare students for success in an increasingly data-driven and technologically advanced world.

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The Effectiveness of Visual Number Card Media in Enhancing the Counting Skills of Students with Mild Intellectual Disabilities

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Abstract: This study aimed to examine the extent to which the use of pictured number card media influences the counting ability of students with mild intellectual disabilities at the Special School (Sekolah Khusus/Fauzan SKh) in Serang Regency. the primary research question was whether the use of pictured number card media had a significant effect on the counting skills of students with mild intellectual disabilities at Fauzan Special School. The hypotheses of this study comprised a null hypothesis (Ho), which stated that the media had no effect on the students' counting skills, and an alternative hypothesis (H1), which posited a significant effect. The study employed a pre-experimental method using a one-group pretest-posttest design. The population consisted of 23 students with special needs, from which a sample of 10 students with mild intellectual disabilities was selected. Data were collected through tests, observations, and documentation. The results, analyzed using the Wilcoxon Matched Pairs test at a significance level of 0.05, yielded ap-value of 0.005. Since this value was less than 0.05, the null hypothesis (Ho) was rejected. These findings indicated that the use of pictured number card media significantly improved the counting skills of students with mild intellectual disabilities.

Keywords: visual number card; counting ability; mild intellectual disabilities

A. Introduction

Education is a right for every citizen, including children with special needs. Children with physical or mental disabilities in society can be categorized into various types and characteristics based on the specific challenges they face. One group of children with special needs that requires particular attention in the learning process is students with mild intellectual disabilities. According to the results of the Stanford-Binet and Wechsler (WISC) tests, individuals with mild intellectual disabilities have an IQ range of 50–70. They belong to a group whose intelligence and social adaptability are limited; however, they still possess the ability to progress in academic learning (Minsih, 2020). Although students with mild intellectual disabilities have intellectual capacities slightly below average, they still have the potential to grow and learn, particularly in fundamental areas such as numeracy skills. Counting is the process of recognizing and determining the number of objects by associating them with numerical concepts, starting from the number one (Malapata & Wijayanigsih, 2019).

Numeracy skills are a fundamental foundation in everyday life. Mastery of number concepts and basic arithmetic operations enables individuals to solve practical problems, manage simple finances, and participate more actively in social environments. For students with mild intellectual disabilities, the development of counting abilities is not only crucial for future academic success but also for fostering independence and enhancing their overall quality of life.

However, the process of learning to count for students with mild intellectual disabilities often faces challenges. Their cognitive characteristics, such as shorter attention spans, difficulty with abstraction, and slower learning pace require a more concrete, visual, and engaging instructional approach. Conventional teaching methods, which tend to be abstract and verbal, are often less effective in stimulating the understanding of counting concepts in students with mild intellectual disabilities. Therefore, in this context, the use of appropriate learning media plays a crucial role in influencing students' interest in learning mathematics.

Various studies have demonstrated the effectiveness of using visual media in enhancing conceptual understanding among students with special needs. For instance, research conducted by Danang showed that the use of dot cards had a positive impact on the counting abilities of students with intellectual disabilities (Purnomo et al., 2019), Similarly, Hidayat and Machdarini found that students' numeracy skills improved when using counting media such as tasbih bead bags (Machdarini & Hidayat, 2021). Ika and Faiz utilized Busy Books to train counting skills in students with intellectual disabilities, which also proved effective in enhancing their numeracy abilities (Puspitasari & Noormiyanto, 2021). Furthermore, Jimenez reported that the use of story-based learning media can foster the development of students' numeracy skills through Story-Based Math (Jimenez, B. A., & Kemmery, 2013). Therefore, based on these previous studies, it can be concluded that students with intellectual disabilities have the potential to develop their numeracy skills, provided that the appropriate teaching strategies are employed, one of which includes the use of effective learning media

One of the media that can be used in mathematics learning, particularly in teaching counting skills, is pictorial number cards. These cards contain images, text, numbers, or symbols that help remind students of concepts related to the images displayed. According to Fitriani et al., pictured number cards are effective for helping lower-grade students recognize numerical symbols ((Fitriani et al., 2022) ; (Gunardi et al., 2022)) and they can enhance elementary students' understanding of number concepts (Nurfitri et al., 2022). However, the use of pictured number cards in teaching number concepts has mostly been tested on students without special needs. Research that specifically examines the effect of pictured number cards on the counting abilities of students with mild intellectual disabilities remains relatively limited. Therefore, this experimental research entitled "The Effectiveness of Pictured Number Card Media on Improving the Counting Ability of Students with Mild Intellectual Disabilities" is considered important to conduct. This study aims to empirically examine whether the use of pictured number card media has a positive impact on improving the counting skills of students with mild intellectual disabilities. The findings of this research are expected to make a significant contribution to the development of more effective and innovative counting instruction strategies for students with mild intellectual disabilities, as well as to provide a foundation for the creation of instructional media that better meet their specific needs.

B. Methods

This study used a pre-experimental approach with a one-group pretest-posttest design, as it involved only one group without a control group (Rukminingsih et al., 2020). The population consisted of 23 students enrolled at Fauzan Special School (*Sekolah Khusus/SKh*) in Bojonegara, Serang Regency, Banten Province. A purposive sampling technique was used to select 10 students identified as having mild intellectual disabilities.

The intervention process involved three main stages: (1) administering a **pretest** to assess the students' initial counting abilities, (2) implementing the treatment using pictured number card media, and (3) conducting a **posttest** to evaluate any changes in their performance.

Data were collected using validated and reliable test instruments, alongside observations and documentation. The data were analyzed using both descriptive and inferential statistical methods. Descriptive statistics involved calculating the mean and N-Gain scores to determine the degree of improvement. For hypothesis testing, the Wilcoxon Matched Pairs Test was employed due to the small sample size and the non-normal distribution of the data. The hypotheses were as follows:

H_o: $\mu_1 = \mu_2$

H_a: $\mu_1 > \mu_2$

H_o : There was no difference in the students' counting skills before and after the use of pictured number card media.

H_a : The students' counting skills after the use of pictured number card media was significantly better than before.

C. Results and Discussion

The study's findings included both descriptive statistics of students' counting skills and the results of hypothesis testing. The pretest and posttest scores showed a marked improvement in performance following the use of the pictured number card media.

1. Results of Descriptive Statistical Analysis of Pretest and Posttest

Table 1. Mean Scores of Pretest and Posttest

Student	Scores of Pretest	Scores of Posttest
S1	50	86
S2	33	67
S3	50	86
S4	17	50
S5	17	50
S6	33	67
S7	33	86
S8	33	67
S9	17	50
S10	17	67
Mean	30	67.7

Based on the information in Table 1, it can be seen that the students' counting skills improved significantly, with the average score increasing from 30 to 67.7. an improvement of 37.7 points. To further examine the extent of this improvement, an N-Gain test was conducted using the following formula.

$$N - Gain = \frac{Score\ of\ post\ test - Score\ of\ pre\ test}{ideal\ score - score\ of\ pretest}$$

By inputting the pretest and posttest scores, information was obtained regarding the category of improvement in each student's counting skills as well as that of the group as a whole, as shown in Table 2 below.

Table 2. N-Gain of Students' Counting Skill Improvement

Student	Scores of Pretest	Scores of Posttest	N-gain	Category
S1	50	86	0.72	High
S2	33	67	0.50	moderate
S3	50	86	0.72	High
S4	17	50	0.39	moderate
S5	17	50	0.39	moderate
S6	33	67	0.50	moderate
S7	33	86	0.79	High
S8	33	67	0.50	moderate
S9	17	50	0.39	moderate
S10	17	67	0.60	moderate
Rata-Rata N-Gain			0.55	moderate

Based on the table 2, it is obtained that 3 people (30%) experienced improvement in the high category and 7 people (70%) in the moderate category. Meanwhile, when viewed overall, the average improvement falls into the moderate category.

2. Hypothesis Testing

For the process of generalizing conclusions, hypothesis testing was then carried out using a non-parametric statistical test, namely the Wilcoxon Matched Pairs test, using SPSS 20. The Wilcoxon Matched Pairs test was used for samples that came from the same subjects or the same class. This hypothesis test was conducted to determine whether there was a significant difference in the average results between the pretest and posttest. The decision rule for the hypothesis test using the Wilcoxon Matched Pairs test is as follows:

a. If the sig. value (2-tailed) < 0.05, there is a significant difference between the learning outcomes in the pretest and posttest data.
b. If the sig. value (2-tailed) > 0.05, there is no significant difference between the learning outcomes in the pretest and posttest data

Table 3. Wilcoxon Matched Pairs Test Output

Test Statistics[a]

	POSTEST - PRETEST
Z	-2.820[b]
Asymp. Sig. (2-tailed)	.005

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

From the data processing, it was obtained that the Sig. value (2-tailed) was 0.005 < 0.05, so it can be concluded that there was a significant difference between the learning outcomes in the pretest and posttest data. Therefore, based on these results, it shows that there was a significant effect of the picture number card media on the counting skills of students with mild intellectual disabilities

3. Discussion

The data analysis results in this study consistently show a significant effect of using picture number card media on improving the counting ability of students with mild intellectual disabilities. The average increase in students' counting ability from 30 to 67.7 after the implementation of this media indicates the effectiveness of picture number cards as a substantial learning aid. The difference of 37.7 points quantitatively illustrates how this media positively contributes to the understanding of number concepts and basic arithmetic operations in students.

Furthermore, the results of the N-Gain test provide a deeper perspective on the level of improvement experienced by the students. The majority of students (70%) showed improvement in the moderate category, while a small portion (30%) achieved improvement in the high category. Although the average improvement overall falls into the moderate category, this distribution shows that the picture number card media can have a positive impact on most students in the research group, with some students demonstrating remarkable progress. This suggests that the media has the potential to accommodate varying levels of students' initial understanding.

The hypothesis test results, which revealed a significance value (Sig.(2-tailed)) of 0.005, lower than the set significance level ($\alpha = 0.05$), provided strong evidence that the difference between the pretest and posttest data is significant. Thus, it can be concluded that the intervention using picture number card media significantly influences the counting skills of students with mild intellectual disabilities.

Picture number card media offers an interesting and promising alternative for addressing learning challenges in students with mild intellectual disabilities. The picture number cards combine numerical representation with concrete visualization through images. This combination can help students with mild intellectual disabilities better understand number concepts, associate number symbols with quantities, and increase their interest and motivation in learning to count. These findings align with learning principles that emphasize the importance of using visual and concrete media to facilitate understanding of abstract concepts, especially for students with learning difficulties or special educational needs, such as mild intellectual disabilities ((Park et al., 2020) ; (Saunders et al., 2016)). The combination of numbers and images in this media also has the potential to enhance students' imagination, engagement, motivate them to learn, and assist in processing information more effectively (Sanusi et al., 2020).

The implications of this study have significant practical relevance in the context of inclusive education. These findings provide empirical support for educators, therapists, and other stakeholders to consider and implement picture number card media as an effective learning strategy to improve the counting ability of students with mild intellectual disabilities. The use of this media can be a valuable alternative or complement to traditional teaching methods, which may be less suitable for the learning styles and needs of students with these characteristics. Previous research also shows the effectiveness of using visual media in improving mathematics comprehension for students with special needs ((Hastuti et al., 2023) ; (Wijayanti et al., 2022))

Although the results of this study showed a significant effect, it still had some limitations, such as the relatively small sample size (n=10), which may limit the generalization of the findings to a larger population. In addition, the experimental design was less rigorous because it uses a pre-experimental design. To achieve stronger validity, future research is necessary, involving a larger number of participants and using a more rigorous experimental design. Furthermore, future studies could explore other aspects, such as the impact of the duration of media use, variations in the design of the picture number cards, and the integration of this media with other learning strategies to achieve more optimal results.

Overall, this study makes a valuable contribution to understanding the effectiveness of picture number card media as a tool to improve the counting ability of students with mild intellectual disabilities. Strong evidence from both descriptive and inferential analysis indicates that this media has great potential to support the development of mathematical skills in students with special needs. These findings encourage the adoption of visual and concrete media in inclusive education practices and open opportunities for further research to optimize its use in various learning contexts

D. Conclusion

Based on the data analysis that has been conducted, it can be concluded that there is a significant effect of using picture number card media on improving the counting skills of students with mild intellectual disabilities. This is supported by several key findings. First, there was a significant improvement in the average counting ability of students, from 30 at the pretest stage to 67.7 at the posttest stage, with an increase of 37.7 points. Furthermore, the N-Gain analysis showed that the majority of students (70%) experienced improvement in counting ability in the moderate category, while a smaller portion (30%) showed improvement in the high category. Overall, the average improvement in students' counting skills falls into the moderate category. The hypothesis test results showed a significance value (Sig.(2-tailed)) of 0.005, which was smaller than the significance threshold ($\alpha=0.05$). This indicates that there was a real and significant difference in the average counting skills of students before and after using the picture number card media.

Therefore, the results of this study provide empirical evidence that the use of picture number card media is effective in improving the counting ability of students with mild intellectual disabilities. These findings imply that visually engaging and concrete media, such as picture number cards, can be a valuable alternative or complement in mathematics learning strategies for students with such characteristics.

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