THE EFFECT OF MULTIPLE INTELLIGENCE-BASED MATHEMATICS LEARNING MATERIALS ON MATHEMATICAL REASONING ABILITY BASED ON INITIAL ABILITY OF STUDENTS

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DOI: 10.5281/zenodo.11059283

Abstract

Mathematical reasoning ability is the foundation for understanding and practicing mathematics and plays a crucial role in problem-solving. Typically, every mathematical task necessitates critical reasoning, which often remains suboptimal and thus requires enhancement. This implies that teachers need to take into consideration the intelligence and learning styles of students. Therefore, this research aimed to assess the impact of mathematics learning materials based on multiple intelligence on mathematical reasoning ability, considering the initial ability of students. A 2x2 factorial design was used, with mathematical reasoning ability being the dependent variable, while multiple intelligence-based learning materials and initial ability were considered as the independent and moderating variables, respectively. The mathematical reasoning ability of eighth-grade students from State Junior High School 7 Padang was analyzed using t-tests, u-tests, and a two-way ANOVA. The results showed that students taught with multiple intelligence-based learning materials had better mathematical reasoning ability than those taught through conventional methods, although the difference was not significant. This observation was valid for both general performance and when considering initial ability. Additionally, there was no observed interaction between initial ability and the learning model concerning mathematical reasoning ability. The final result showed that multiple intelligence-based learning materials had a positive impact on mathematical reasoning ability.

Keywords: Learning Material, Multiple Intelligence, Mathematical Reasoning Ability, Initial Ability.

INTRODUCTION

Mathematical reasoning ability is the foundation for understanding and practicing mathematics and plays a crucial role in problem-solving (Chotimah et al., 2020; Jumiarsih et al., 2020). According to Jeannotte & Kieran (2017), mathematical reasoning is a crucial component in the field of mathematics education. NCTM (2000) also described various abilities in this context, which included drawing logical conclusions, explaining models, facts, properties, relationships, or patterns, estimating answers and solution processes, using relationship patterns to analyze situations or make analogies, generalizations, and conjectures, posing counterexamples, following rules of inference, checking argument validity, proving, and constructing valid arguments, and constructing direct, indirect, and mathematical induction proofs.

Teachers should create a challenging learning environment to improve the mathematical reasoning ability of students, rather than simply completing exercises in class (Lannin et al., 2011). Every mathematics activity inherently includes thinking (Fedistia & Musdi, 2020), and developing mathematics interpretation for students is a crucial part of teaching and learning. Students can make conjectures, provide evidence, work on mathematics problems, and draw accurate conclusions. Furthermore, learners also improve critical thinking when facing problems, as signified by (Rosyidah et al., 2022), showing that mathematics is based on reasoning. Learning mathematics turns into an ordinary imitation when critical thinking is not encouraged in learners.

According to the 2011 TIMSS results, Indonesia ranked 38th out of 42 countries with an average score of 386. Less than one-fifth of students, specifically 17%, showed proficiency in mathematical reasoning, falling significantly short of the international passing threshold of 30% (Kurniawati & Ramlah, 2021). The current level of ability is suboptimal, showing a need for improvement in reality. Furthermore, the 2018 PISA results showed that the Indonesian mathematical reasoning ability of students remains relatively low (Nurazizah & Zulkardi, 2022). This lack of ability is further supported by Jumiarsih (2020) and Sumarsih (2018), who observed that students often lack engagement in reasoning. Siregar (2016) showed that students struggled to provide evidence, work on problems, and draw conclusions, often answering questions without forming conjectures first. The situation arises from suboptimal tutoring methods where teachers frequently use a one-size-fits-all approach.

Teachers should have the ability to design differentiated learning that is associated with the characteristics of students (Abenti, 2020). Differentiated learning includes adjusting teaching to meet students' needs (VanTassel-Baska, 2012). This approach is supported by the theory of multiple intelligence, which reflects the learning styles of students, needs, and interests, making it more effective (Cocking et al., 2000). Boulmaiz (2017) stated that the theory of multiple intelligence contributed to learning by connecting and considering the needs, potential, styles, and intelligence of students. Therefore, teachers should pay attention to the intelligence and learning styles of learners (Sunendar, 2017).

Students show diverse intelligence and learning styles, collectively known as multiple intelligence (Maharani et al., 2020). Intelligence is defined as the ability of individuals to perceive and solve problems (Taufik & Adiastuty, 2017). Intelligence is also a critical factor in determining the success of students or failure in learning (Oktarina et al., 2021). Having a higher level of intelligence does not automatically ensure success in school. Moreover, students with lower intelligence levels may struggle to stay highly motivated (Xu, 2020).

According to Aini et al. (2018), every individual has various types of intelligence, which include linguistic-verbal, logical-mathematical, visual-spatial, musical, kinesthetic, intrapersonal, interpersonal, and naturalistic intelligences (Armstrong, 2018; González-Treviño et al., 2020). Linguistic intelligence includes strong verbal ability in both speaking and writing. Logical-mathematical intelligence relates to problem-solving, effective use of numbers, understanding cause-and-effect relationships, and recognizing patterns. Furthermore, visual-spatial intelligence includes knowledge of space and graphics, such as drawing, painting, visual arts, architecture, navigation, and well-developed mental imagery. Musical intelligence is the ability to recognize composition and performance in rhythm, pitch, melody, and music. Kinesthetic intelligence includes using the entire body to express ideas and emotions, as well as hands for production or modification. Intrapersonal intelligence is about recognizing personal feelings, fears, and motivations, interpersonal intelligence is the ability to understand and respond to the feelings, emotions, attitudes, and actions of others. Naturalistic intelligence is related to recognizing and categorizing various types of living beings (Alsalhi, 2020; Taase, 2012).

The intelligence characteristics individuals possess impact the way they approach learning (Abenti, 2020; Fathani, 2019). According to Arns (2021), each child has specific intelligence and understanding styles that uniquely support the learning of a child. Using various forms of intelligence allows teachers to develop materials that use different learning styles (Andriani et al., 2021). The intelligence also helps in recognizing the interests and talents of students (Erdem & Keklik, 2020), facilitating a better understanding of learners by teachers (González-Treviño et al., 2020). The use of multiple intelligence makes the teaching and learning process more enjoyable (Abenti, 2020) and improves teacher performance through various teaching methods and strategies (Ahanbor & Sadighi, 2014; Al-Qatawneh et al., 2021) including technology (Cocking et al., 2000), and promoting engagement with different cultures (B. Shearer, 2018). Multiple intelligence is a result of the interplay between the two hemispheres of the human brain which include the left and the right (González-Treviño et al., 2020; Meneviş & Özad, 2014). The left brain excels in solving mathematical, logical, and concrete problems, and the right brain is skillful at responding to qualitative, artistic, and abstract concepts, all in the framework of understanding the external world. Students with intrapersonal intelligence prefer private learning, while those who have interpersonal intelligence flourish in group settings (Yerizon et al., 2018). Developing interpersonal intelligence includes group tasks, while intrapersonal intelligence is nurtured through independent learning at home, reflecting on math-acquiring experiences, and expressing opinions on projects (Maharani et al., 2020).

Kinesthetically intelligent students flawlessly incorporate physical movement and thought, leading to flawless motion (Yerizon & Putra, 2021). Those with high logical-mathematical intelligence typically excel in logical problem analysis, abstract relationship understanding, logical thinking, and effective argumentation. This intelligence can be improved through activities such as solving algebraic problems, calculus, quadratic equations, and logical analysis (Maharani et al., 2020). Additionally, students with visual intelligence possess a strong ability to observe objects in detail (Ndia et al., 2020). All these intelligences may coexist in the same class, and teachers need to improve learners through various activities. Teachers can guide learners in drawing graphs, tables, and curves in materials that lend students to visualization (Jahroh & Baidi, 2022; Maharani et al., 2020).

The theory of multiple intelligence is essential in education as it considers intelligence to be the foundation of human activities (Alsalhi, 2020). This theory offers an effective approach to educating and communicating with students in different classroom environments (Abenti, 2020). Previous research showed that learning based on multiple intelligences could improve mathematical literacy (Panjaitan, 2023), critical thinking (Yerizon et al., 2023), and general learning results (Junita et al., 2023). There is currently no specific material that accommodates all these intelligences despite the results. Therefore, there is a need to improve the mathematical reasoning ability of students. This research aims to assess the impact of mathematics learning materials based on multiple intelligence on mathematical reasoning ability, taking into account the initial ability of learners.

METHOD

This research used a 2x2 factorial experiment design, with mathematical reasoning ability as the dependent variable, learning using multiple intelligence-based materials as the independent variable and the initial ability of students as the moderating variable. The result included eighth-grade students from State Junior High School 7 Padang.

ISSN 1462 2815

Table 1: Research Design

Initial Ability (A)	Multiple Intelligence-Based Learning Materials	
	Experiment (B_1)	Control (B_2)
High (A_1)	A_1B_1	A_1B_2
Low (A_2)	A_2B_1	A_2B_2

Description:

A_1B_1 : Mathematical reasoning ability of experimental class students with high initial ability

A_1B_2 : Mathematical solving competence of control class students through high initial ability

A_2B_1 : Mathematical analyzing ability of experimental class students with low initial ability

A_2B_2 : Mathematical thinking ability of control class students through low initial ability

Data analysis included t-tests and u-tests to identify differences in mathematical reasoning ability between the experimental and control classes, considering initial ability. A two-way ANOVA test explored the interaction between initial ability and the learning model on the mathematical reasoning ability of students. The assessment of mathematical reasoning ability used a rubric describing signs for each response of students, and before the analysis, normality, and homogeneity tests were conducted for both samples.

RESULTS AND DISCUSSIONS

A. Data Description

The results of the mathematical reasoning ability test were presented with the number of students (N), average $(\bar{x})$, and standard deviation (s) in Table 2.

Table 2: Results of Mathematical Reasoning Ability Test Data Calculation

Class	Group	N	$\bar{x}$	s
Experimental	High	14	73.21	13.24
	Low	10	76.50	10.01
	Total	24	74.58	11.88
Control	High	9	77.78	16.22
	Low	16	66.25	19.19
	Total	25	70.40	18.70

The average mathematical thinking ability of students taught with multiple intelligence-based materials surpassed conventional learning. However, the total standard deviation showed that mathematical reasoning ability records were more evenly distributed in the control class compared to the experimental class, where the standard deviation was smaller. The average mathematical reasoning ability of students with high initial ability in the experimental class was lower than in the control class when analyzing further. This discrepancy arose because the control class already possessed high initial proficiency. The standard deviation data showed a broader distribution of mathematical analyzing competence records in the control class compared to the experimental class, where the standard deviation was smaller.

Students with low initial ability in the experimental class showed higher average mathematical thinking ability than other counterparts in the control class. However, the maximum value showed that the mathematical reasoning ability of students with low initial competence in the experimental class was still lower than in the control class. The standard deviation data demonstrated a more focused distribution of scores in the experimental class compared to the control class similar to the high initial ability group.

B. Analysis Testing Requirements

The process of statistical hypothesis testing commenced with the requirement analysis. The data in the examination were the results of mathematical reasoning ability tests conducted on students who were taught using either multiple intelligence-based learning materials or conventional methods. Furthermore, the gathered data included the performance of students with both high and low initial abilities in both experimental and control classes. Initial analyses included normality and homogeneity tests, conducted through the Kolmogorov-Smirnov and Levene tests, respectively.

1. Normality Test

Table 3 showed the results of the normality test for mathematical reasoning ability tests conducted on students in both the experimental and control classes.

Table 3: Results of Normality Test for Mathematical Reasoning Ability of Students

Class	Group	Sig.	Description
Experiment	High	0.149	Normal
	Low	0.200	Normal
	Total	0.146	Normal
Control	High	0.002	Not Normal
	Low	0.185	Normal
	Total	0.019	Not Normal

The normality test for mathematical reasoning ability in the experimental class produced a significance value exceeding 0.05. This implied that the data from mathematical reasoning ability tests in the experimental class followed a normal distribution. However, the normality test for the control class did not yield significance values exceeding 0.05, and only students with low initial ability showed a normal distribution. The table above also showed that the significance value for mathematical reasoning ability, considering both high and low initial abilities, was greater than 0.05. This implied that the data in both the experimental and control classes showed a normal distribution.

2. Homogeneity Test

The results of the homogeneity test for mathematical reasoning ability in the experimental class were shown in Table 4. The condition for assessing variance homogeneity was a significance value greater than 0.05, showing homogenous variance in the data.

Table 4: Results of Homogeneity Test for Mathematical Reasoning Ability of Students

Group	Sig.	Description
High	0.777	Homogeneous
Low	0.270	Homogeneous
Total	0.484	Homogeneous

Table 4 showed that the total variance homogeneity test for mathematical reasoning ability produced a significance value of 0.484 (> 0.05), implying homogenous variance in the data. The significance value for students with high initial ability in the mathematical thinking ability tests was 0.777 (> 0.05), showing homogenous variance in the data. Similarly, for learners with low initial ability, the significance value was 0.270 (> 0.05), signifying homogenous variance in the data.

C. Hypothesis Testing

Based on the normality and homogeneity tests, it was evident that the data on the mathematical reasoning ability of students were not normally distributed but possessed homogenous variance. The data were subjected to u-tests to compare mathematical reasoning ability between the experimental and control classes. To assess interaction, a two-way ANOVA test was used.

1. First Hypothesis

The hypothesis test aimed to determine whether the mathematical reasoning ability of students taught with multiple intelligence-based learning materials was greater than conventional learning. u-tests were selected for hypothesis testing due to the data not being normally distributed and having a homogenous variance. The results of the first hypothesis test were shown in Table 5.

Table 5: Difference in Average Scores of Mathematical Reasoning Ability Test of Students

Class	N	Average	u	z	Asymp. Sig.
Experiment	23	73.21	252.00	-0.959	0.338
Control	26	70.40			

The Asymp. Sig value was 0.338 (> 0.05), recommending that mathematical reasoning ability of students taught with multiple intelligence-based learning materials was equivalent to conventional acquiring.

2. Second Hypothesis

Another hypothesis test focused on determining whether mathematical reasoning ability of students with high initial ability, taught through multiple intelligence-based learning materials, surpassed conventional acquiring. t-test was selected for this hypothesis test as the data was normally distributed but had non-homogeneous variance. The results of the second hypothesis test were shown in Table 6.

Table 6: Difference in Average Scores of Mathematical Reasoning Ability Tests with High Initial Ability of Students

Class	N	Average	u	Z	Asymp. Sig.
Experiment	14	73.21	62.50	-0.453	0.651
Control	9	77.78			

The Asymp. Sig value was observed as 0.651 (> 0.05), showing that mathematical reasoning ability of students with high initial ability taught through multiple intelligence-based learning materials was equivalent to conventional understanding.

3. Third Hypothesis

This hypothesis test aimed to determine whether students with low initial ability, when taught through multiple intelligence-based learning materials, showed improved mathematical reasoning ability compared to conventional learning. The testing used t-test, given the normal distribution of data and homogeneous variance, and results from the third hypothesis test were shown in Table 7.

Table 7: Difference in Average Scores of Mathematical Reasoning Ability Tests with Low Initial Ability of Students

Class	N	Average	u	Z	Asymp. Sig.
Experiment	10	76.50	45.50	-1.531	0.126
Control	16	66.25			

The Asymp.sig value was 0.126 (> 0.05), showing that mathematical reasoning ability of students with low initial ability, taught through multiple intelligence-based learning materials, was equivalent to conventional learning.

4. Fourth Hypothesis

Another hypothesis test aimed to determine the interaction between initial ability and the learning model on mathematical reasoning ability of students, and this testing used the SPSS 20 for Windows software, with results shown in Table 8.

Table 8: Interaction Between Initial Ability and Learning Models on Mathematical Reasoning Ability Students

Source of Variation	Sum of Squares	df	Middle Square	F	Sig.
Initial Ability	93.72	1	93.72	0.390	0.535
Learning Model	196.88	1	196.88	0.819	0.370
Interaction	635.98	1	635.98	2.647	0.111
Error	10813.41	45	240.30		
Total	269050	49			

The significance value in the interaction row was 0.111 (> 0.05), showing the acceptance of H_0, meaning there was no interaction between initial ability and the learning model in determining the mathematical reasoning ability of students which could be seen in Figure 1.

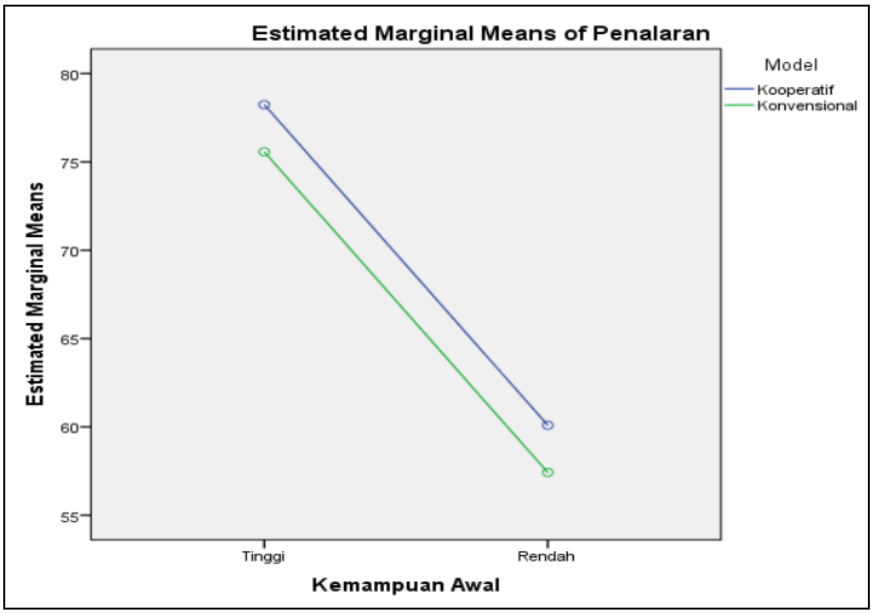

Figure 1: Interaction Graph between Initial Ability and Learning Model on Mathematical Reasoning Ability of Students

The results of this research diverged partially from Panjaitan (2023) and Yerizon (2023), showing that multiple intelligence-based mathematics learning could improve mathematical literacy and critical thinking ability of students. Comparing the findings to those of Anwar (2020), it was observed that, following the use of multi-intelligence-based learning materials for trigonometry, 19.35% of students achieved a moderate level, 64.52% reached a high level, and 16.13% reached a very high level. This showed a positive impact of multi-intelligence-based learning on the mathematical abilities of the learners. Ayesha (2013) found a significant positive correlation between multiple intelligence and academic achievement. Ozdilek (2010) discovered a positive connection between logical-mathematical, visual-spatial, and interpersonal intelligence and the academic performance of elementary school students in Turkey. Furthermore, Gürkan (2019) also found that the use of multiple intelligences positively affected the interest and participation of students by engaging all eight types of intelligences and student-acquiring styles. Several possible reasons for the lack of difference in mathematical reasoning ability of students in this research included ineffective learning due to a combination of online and offline classes, limited face-to-face interactions, only six sessions, and restrictions on activities that could be performed in the classroom.

Each student possessed different intelligences (Abenti, 2020; Alsalhi, 2020) and had unique learning styles (Abenti, 2020). These distinct intelligences played a crucial role in determining the prospects of students for achieving successful academic performance (González-Treviño et al., 2020). Recognizing individual differences in each learner enabled teachers to provide shaped guidance and recommend strategies for the success of students. Furthermore, the consideration of the multiple intelligences of learners was important as it influenced educational communication (Abenti, 2020) and the intellectual capacities of learners in the classroom (Almeida et al., 2010). Since students did not learn in the same way, each unique teaching style of teachers was based on the combination of multiple intelligences. Previous research recommended that applying multiple intelligences in the classroom could improve the academic development of learners (Ghamrawi, 2014). Teachers were encouraged to use different intelligences to include a broader range of students in the learning process (Abenti, 2020). Additionally, environmental conditions were observed to influence cleverness (Lucas et al., 1998). It was previously believed that intellect had fixed characteristics that could not be changed (Jensen, 1998). Gardner (1983) proposed a view that intelligence was a mix of inherent potential and ability that can develop in various ways. In more recent perspectives, intellect is defined as the capacity of an individual to perform tasks in a specific manner (Agustini et al., 2019). Students who grasped mathematical concepts well could effectively solve problems, supported by the unique intelligence each student possessed (Jayanti et al., 2020), and students preferred interpreting self-understanding (Rivai et al., 2020).

The development of human thought was closely connected to education through the curriculum, where textbooks represented the essence of education (Alsalhi, 2020; Taase, 2012). The theory of multiple intelligences were included in the curriculum at the elementary, secondary, and tertiary levels. This application of the theory in the classroom had been implemented in various countries, such as India (Chakraborty, 2010), Iran (Moheb & Bagheri, 2013), Singapore (Kaewkiriya et al., 2016), Romania (Oprescu & Oprescu, 2012), and South Africa (Gouws, 2007). Therefore, it was crucial to integrate multiple intelligences into textbooks through texts, activities, and exercises

(Al-Qatawneh et al., 2021). Common types of intelligence found in textbooks included linguistic-verbal, visual-spatial, intrapersonal, and interpersonal intelligence. In addition, musical, kinesthetic, and naturalistic intelligences were seldom addressed in textbooks (Ebadi et al., 2015; Kirkgöz, 2010; Taase, 2012). Gürkaynak (2015) showed that kinesthetic and interpersonal intelligence dominated textbooks. General intelligence was most closely associated with linguistic-verbal and logical-mathematical intelligence (C. B. Shearer & Karanian, 2017). An analysis showed that the dominant intelligences of students were kinesthetic, interpersonal, intrapersonal, and musical (Carlín et al., 2013). The analysis supported differentiated learning in the classroom by considering the multiple intelligences of students (Adcock, 2014). According to Hassan (2020), incorporating multiple intellects in teaching geometry led to increased active participation among primary school students in Egypt.

Alsalhi (2020) found that the level of awareness among teachers regarding the incorporation of multiple intelligences into textbooks varied based on gender, education, and experience. Al-Qatawneh (2021) showed that teacher awareness of the importance of joining the theory of multiple intelligence into textbooks needed improvement. Schrand (2008) used interactive media to engage various multiple intelligences of students, creating an active learning environment. This described how communication through interactive media could control multiple intellects of students. The use of technology greatly assisted teachers in applying this theory to blended learning (Chakraborty, 2010). Kaewkiriya (2016) used e-learning to solve the needs of learners with multiple intellects. Ahanbor (2014) found that learning styles developed independently of gender-related connections, and there was a relationship between multiple intelligences and learning styles. This showed the need for teachers to change teaching methods in the classroom. Gonzalez-Trevino (2020) discovered that male students showed higher intrapersonal intelligence compared to females, contrasting with the findings of Menevis (2014), where females showed better intrapersonal intelligence than males. The research by Llor (2012) in Spain showed that male students had logical-mathematical and interpersonal intelligences, while females had interpersonal and intrapersonal intelligences, therefore, male and female students required different teaching methods. There were no significant differences in multiple intelligence between the experimental and control groups but, Pekdemir (2015) found that visual-spatial, kinesthetic, musical, interpersonal, and naturalistic intelligences could be improved through drama. Lozano (2007) reported that students with musical intelligence achieved academic success when teachers incorporated background music in the classroom.

CONCLUSION

In conclusion, the results of the data analysis showed that:

1. The total mathematical reasoning ability of students instructed with multi-intelligence-based learning materials was improved, although the difference was not statistically significant when compared to those with conventional methods.
2. Mathematical reasoning ability of students, both with high and low initial ability, who were taught through multi-intelligence-based learning materials, was higher but not significantly different from those with conventional methods.
3. There was no observed interaction between initial ability of students and the training model concerning mathematical reasoning ability.

Acknowledgements

The authors would like to thank Lembaga Penelitian dan Pengabdian Masyarakat Universitas Negeri Padang for funding this work with a contract number 1218/UN35.15/LT/2023.

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