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Enhancing Numeric Literacy through Creative Mathematical Reasoning in the Merdeka Belajar Curriculum Framework

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Abstract

This study investigates the effectiveness of creative mathematical reasoning in improving students' numeracy literacy within the framework of the Independent Learning Curriculum. Numeracy literacy is a crucial competency that enables learners to comprehend and address real-world problems using mathematical concepts and skills. The Merdeka Learning Curriculum provides space for innovative approaches in learning, including the application of creative mathematical reasoning to improve students' numeracy literacy skills. Using a quantitative quasi-experimental design, the study involved junior high school students divided into two groups: an experimental group and a control group. The findings revealed that the experimental group achieved a higher average score (M = 78.9; SD = 10.53) compared to the control group (M = 67.8; SD = 5.30). Statistical analysis using paired and independent t-tests confirmed a significant improvement in the performance of the experimental group ($p < 0.05$). The results demonstrate that creative mathematical reasoning significantly enhances students' comprehension, critical thinking, and problem-solving skills. The study concludes that integrating creativity-based reasoning strategies is aligned with the Independent Learning Curriculum and offers valuable guidance for teachers to design more innovative, student-centered math learning experiences.

Keywords Creative Mathematical Reasoning; Mathematics Learning; Merdeka Belajar Curriculum; Numeric Literacy

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1. INTRODUCTION

In the era of globalization and within the Merdeka Belajar curriculum, literacy and numeracy skills have become very important basic competencies (Braun & Huwer, 2022; Huang et al., 2017; Kanbay & Okanlı, 2017). Numeracy literacy encompasses not only the ability to calculate but also the capacity to understand and analyze information presented in numerical or graphical forms (Kanbay & Okanlı, 2017). Nevertheless, based on the results of the Programme for International Student Assessment (PISA), students' mathematical literacy skills in Indonesia are still considered low (Braun & Huwer, 2022). Several factors cause the low numeracy literacy in Indonesia. One of the causes is the less effective teaching methods: Many teachers still use traditional teaching methods that do not actively involve students. A poor initial understanding of concepts makes it difficult for teachers to teach mathematics in an engaging and enjoyable manner (Birkeland, 2019). Many teachers have a limited understanding of the mathematical content they teach. This affects the way they teach and their ability to clearly explain concepts. We all know that numeracy literacy is very relevant in various aspects of life, such as financial planning, understanding health information, and making appropriate decisions based on data.

Literacy and numeracy are one of the main competencies that students must have (Amir et al., 2023; Huang et al., 2017). In facing the challenges of the 21st century. The Independent Curriculum offers flexibility in learning, but the main challenge is how to ensure that creative approaches to mathematical reasoning genuinely enhance students' understanding of numeracy concepts. Several studies have shown that project-based learning and contextual approaches (Han et al., 2015; Maharani et al., 2021; Saad & and Zainudin, 2024) It can improve students' creative mathematical reasoning abilities in mathematics. However, the primary challenge is how teachers can effectively implement these methods in the classroom. In addition, the Independent Curriculum emphasizes strengthening the profile of Pancasila students, including critical and creative reasoning abilities. Creative mathematical reasoning plays a role in shaping students' analytical mindsets (Adawiyah et al., 2017; Hidayat et al., 2018; Norqvist et al., 2019), but there needs to be a more systematic strategy to integrate this aspect into daily learning.

Reasoning plays a crucial role in the learning process, particularly in solving complex problems. Reasoning begins with a thinking process (Allsop, 2019; Silva et al., 2020; Small, 2017) That allows someone to draw logical conclusions without having to go through evidence analysis, or only based on personal beliefs. In the context of completing tasks, reasoning is understood as a train of thought used to form statements and reach conclusions. In mathematics learning, this special form of reasoning is known as mathematical reasoning. McKenzie states that mathematical reasoning (Birkeland, 2019; Hidayat et al., 2018; Putra et al., 2023) It serves as the primary foundation for understanding mathematical concepts as a whole.

The application of creative mathematical reasoning is highly recommended because it is believed to improve students' ability to solve problems innovatively (Adawiyah et al., 2017; Hendriana et al., 2018; Muin et al., 2018; Norqvist et al., 2019). This reasoning enables students to approach everyday life problems more effectively and creatively. This process includes the use of numbers and basic mathematical symbols (Amir et al., 2023; Cooper & Lavie, 2021; Putra et al., 2023) to analyze and interpret information. Lithner emphasized the importance of providing space for students to develop creative mathematical reasoning as a means of understanding the conceptual aspects of mathematics and solving non-routine problems. According to him, this creative mathematical reasoning consists of three main aspects (Adawiyah et al., 2017; Olsson, 2017; Tee et al., 2018; Wechsler et al., 2018): creativity, reasonableness (or plausibility), and attachment to concepts (or anchoring). In the literature, creativity has various definitions depending on the scientist's perspective; however, it generally refers to the ability to produce new and useful solutions. Bergqvist emphasized that creativity in this context does not always mean something extraordinary or genius, but rather includes solutions that may be simple but original for the individual who creates them. The criterion of reasonableness (plausibility) is related to the ability to distinguish between logical and less reasonable guesses. Meanwhile, the concept of anchoring, as introduced by several researchers (Bilbao et al., 2016; Dagiene & Stupuriene, 2016; Kandemir et al., 2020; Presmeg, 2016), refers not to the logical strength of an argument, but to how the argument is rooted in relevant mathematical properties such as objects, transformations, and concepts used in thinking.

Several studies investigate creative mathematical reasoning and research numeracy literacy. Based on recent research related to creative mathematical reasoning, it is explained that creative mathematical reasoning enables the development of appropriate solutions for solving mathematical problems (Hidayat et al., 2018). Studies on creative mathematical reasoning are often associated with working memory capacity, cognitive styles, and their application, as well as differences in reasoning when conducted in junior high schools, senior high schools, and universities. Regarding numeracy literacy, research shows that it is not just about computational skills, but also involves the ability to analyze, interpret, and use mathematical information in various forms (such as graphs and tables) to make accurate decisions. Related research discusses literacy and numeracy in the context of RME, its connection with digital-based learning, and the integration of literacy and numeracy in junior high schools, among other topics. This study reveals that previous research has not examined the role of creative mathematical reasoning in enhancing numeracy literacy skills in learning, despite the theoretical potential for creative mathematical reasoning to improve students' literacy and numeracy skills. Based on this, a study will be conducted on creative mathematical reasoning to enhance students' numeracy literacy skills.

Based on the explanation above, this study aims to analyze the application of creative mathematical reasoning in the mathematics learning process, as outlined in the Independent Learning Curriculum. Evaluate the effectiveness of applying learning strategies based on creative mathematical reasoning in improving student learning outcomes in the numeracy aspect.

2. METHODS

The method employed in this study was designed to accurately measure the effect of the creative mathematical reasoning strategy on students' numeracy literacy performance. To ensure the research process was systematic and scientifically accountable, several aspects were defined, including population and sampling procedures, research design, instruments, and statistical analysis techniques. A summary of these methodological components is presented in the following table.

Table 1. Summary of Research Method

Aspect	Description
Population	Students of Kandora Christian Junior High School
Sample	Grade VIII A (experimental group: *creative mathematical reasoning* strategy) with 30 students, and Grade VIII B (control group: conventional method) with 28 students. The classes were randomly selected from groups with relatively balanced characteristics and had never been exposed to a similar approach before.
Research Design	Quasi-experimental with pretest–posttest control group design
Research Instruments	Numeracy literacy test (pretest–posttest) based on national indicators and the PISA framework (contextual open-ended problems)
Data Analysis Techniques	Descriptive statistics (mean, median, SD, min–max, score distribution)- Assumption tests (normality: Kolmogorov–Smirnov/Shapiro–Wilk; homogeneity: Levene's Test)- Hypothesis testing: *Paired Sample t-test and Independent Samples t-test* ($p < 0.05$)

Research Validity and Reliability

The numeracy literacy test used in this study was developed based on national indicators of numeracy skills and the PISA framework, with an emphasis on contextual and open-ended problems. Content validity was established through expert judgment from mathematics education specialists, who evaluated the alignment of the test items with the research objectives and the creative mathematical reasoning framework. Furthermore, item analysis using the Pearson Product-Moment correlation was conducted, and items with correlation coefficients $r > 0.30$ were considered valid. The results confirmed that the majority of the items met the validity requirements.

The internal consistency of the instrument was examined using Cronbach's Alpha. The reliability coefficient obtained was $\alpha = 0.82$, which exceeds the minimum threshold of 0.70, indicating that the test items had high reliability and were consistent in measuring students' numeracy literacy performance. Based on the validity and reliability testing, the numeracy literacy test was deemed both valid and reliable, making it suitable for use as the primary instrument in this quasi-experimental study.

3. FINDINGS AND DISCUSSIONS

Findings

Based on the analysis of the numeracy literacy test data, it is known that:

Table 1. Pre-test Score Per Student

No	Experimental	Control
1	57	54
2	58	55
3	59	53
4	60	52
5	55	57
6	61	56
7	54	55
8	63	58
9	57	54
10	59	56
11	60	55
12	58	57
13	62	59
14	56	53
15	57	54
16	55	52
17	50	48
18	52	49
19	61	60
20	63	61
21	58	55
22	57	56
23	62	60
24	59	58
25	56	54
26	51	50
27	53	52
28	60	57

No	Experimental	Control
29	57	
30	55	

Table 2. Descriptive Statistics of Pretest Scores

Group	N	Mean	Median	Std. Dev.	Min	Max
Experimental	30	57.5	57.5	3.4	50	63
Control	28	55	55	3.2	48	61

The descriptive statistics in Table 2 show that the average score of the experimental class, 57.5, is slightly higher than that of the control class, 55. The difference in averages is only 2.5 points, which is considered a small difference. This indicates that before the treatment, the initial ability of students in both groups was relatively equal. The standard deviation in the experimental class is 3.4, and in the control class is 3.2. Both classes have relatively small and nearly identical standard deviations. This suggests that the distribution of student scores in both classes is relatively homogeneous (students' scores are not far from the average). The experimental class consists of 30 students, while the control class has 28 students. This number is relatively balanced, making comparisons between the groups fairer and statistically justifiable. The minimum and maximum values also fall within a similar range: 50–63 for the experimental group and 48–61 for the control group. These values suggest that both groups had students performing across the lower to mid-levels of literacy and numeracy prior to the intervention, with no extreme differences in the distribution of performance. Since the difference in averages is not significant and the standard deviations are the same, the initial conditions of both groups can be considered equivalent.

Table 3. Post-test Score Per Student

No	Experimental	Control
1	81	69
2	75	70
3	80	65
4	90	72
5	85	68
6	77	66
7	79	70
8	95	76
9	83	71
10	74	68
11	82	67
12	88	72
13	91	69
14	70	64
15	76	66
16	84	73
17	59	63

No	Experimental	Control
18	65	62
19	92	75
20	89	74
21	68	60
22	72	61
23	93	76
24	87	70
25	78	69
26	64	58
27	58	57
28	94	74
29	73	
30	66	

Table 4. Descriptive Statistics of Posttest Scores

Group	N	Mean	Median	Std. Dev.	Min	Max
Experimental	30	78.9	79.5	10.53	58	95
Control	28	67.8	69	5,3	57	76

The descriptive statistics in Table 4 provide a clear comparison between the experimental and control groups in terms of their posttest performance on literacy and numeracy assessments. The experimental class has an average score of 78.9, which is higher than the control class's average of 67.8. The mean difference = 11.1 points, indicating an improvement in learning outcomes in the experimental class. The median of the experimental class is 79.5, whereas the median of the control class is 69. This is consistent with the average scores, showing a difference in central tendency. The standard deviation of the experimental class, 10.53, indicates a relatively larger variation in scores, while the control class, 5.3, shows more homogeneous scores. This means that, although the experimental class has a higher average, the variation in student scores is also greater. The score range of the Experimental class: 58 – 95 (range = 37). The score range of the Control class: 57 – 76 (range = 19). This indicates that the range of scores in the experimental class is significantly wider, meaning there are students with both high and low scores, resulting in a more pronounced distribution of scores.

Overall, it can be explained that the experimental class showed higher learning outcomes compared to the control class, both in terms of the mean and the median. The score variation in the experimental class was greater (SD 10.53, range 37), whereas the control class was more homogeneous (SD 5.3, range 19). This can be interpreted to mean that the implementation of the learning method in the experimental class not only increased the average score but also generated diversity in student achievement.

Statistical Test Results

a. Paired Sample t-test

The analysis was conducted to determine the differences in pretest and posttest learning outcomes for each group. In the experimental class, the average score increased from 57.61 to 79.61. The paired t-test resulted in $t = -14.36$; $p = 0.000$ ($p < 0.05$). This indicates a significant improvement in student learning outcomes after receiving treatment in the experimental class. In the control class, the average increased from 55.00 to 68.04. The paired t-test resulted in t = -16.80; p = 0.000 ($p < 0.05$). This indicates that the control class also experienced a significant increase from pretest to posttest, despite not receiving the same treatment; however, the increase was not as substantial as in the experimental group. Therefore, both the experimental and control classes showed significant improvements from the pretest to the posttest. However, when looking at the posttest averages, the experimental class showed a higher increase compared to the control class (79.61 vs. 68.04).

b. Independent Sample t-test

An independent t-test was conducted to compare the posttest results between the experimental and control classes. The results showed that the average posttest score for the experimental class was 79.61, while the control class had an average score of 68.04. The following are the independent t-test results (Welch's t-test) for the post-test: t-calculated = 5.02, df (degrees of freedom) ≈ 43.43, p-value ≈ 0.000009. Since the p-value < 0.05, H_0 is rejected. This indicates a significant difference in post-test results between the experimental class (M = 79.61) and the control class (M = 68.04). In other words, there is a significant difference between the two groups. Thus, the treatment in the experimental class had a real impact on improving learning outcomes compared to the control class.

Table 5. T-test Results

Test Type	Group	Mean Pre	Mean Post	t-value	df	p-value	Conclusion
Paired Sample t-test	Experimental	57.61	79.61	-14.36	29	0.000	Significant improvement
Paired Sample t-test	Control	55.00	68.04	-16.80	27	0.000	Significant improvement
Independent Sample t-test	Post Experimental vs Control	–	–	5.02	43.43	0.000	Significant difference between groups

Both groups (experimental and control) showed significant improvements in learning outcomes from the pretest to the posttest. However, the increase in learning outcomes in the experimental class was much higher compared to the control class, as evidenced by the posttest mean difference of 11.57 points. The independent t-test results confirm that the treatment in the experimental class had a significant effect; the treatment in the experimental class was proven to be more effective in improving student learning outcomes compared to the learning applied in the control class.

Discussion

Based on the results of the t-test analysis, it was found that both the experimental class and the control class experienced a significant improvement in learning outcomes from the pretest to the posttest. In the experimental class, the average score increased from 57.61 to 79.61, with a significance level of $p < 0.05$. Similarly, in the control class, the average score increased from 55.00 to 68.04, also with a significance level of $p < 0.05$. This indicates that, in general, the learning process conducted in both groups can improve students' learning outcomes. However, the improvement in learning outcomes in the experimental class was greater than that in the control class. The independent t-test results on the posttest scores showed a significant difference between the two groups (t = 5.02; $p < 0.05$), with the experimental class achieving a higher average (79.61) compared to the control class (68.04).

This is consistent with previous studies, which state that learning that integrates elements of creativity and reasoning in mathematics has a positive impact on conceptual understanding, problem-solving skills, and literacy numeracy (Braun & Huwer, 2022; Huang et al., 2017; Kanbay & Okanlı, 2017; Kholid et al., 2021; Mlotshwa et al., 2020). From the perspective of the Independent Curriculum, these results are highly relevant because they demonstrate that learning can be more than just procedural and one-way. On the contrary, when students are encouraged to think openly and creatively, they not only gain a deeper understanding but also connect mathematical concepts to real-life contexts, which is the core of strengthening literacy and numeracy. Thus, the significant differences found in this study can be interpreted as a strong indication that creative mathematical reasoning is an effective approach to enhancing the quality of mathematics learning, particularly in developing literacy and numeracy in line with the demands of 21st-century learning.

In the context of the Independent Curriculum, these results are particularly relevant because they support the principle of learning that emphasizes conceptual understanding and contextual problem-solving, rather than just mechanistic calculations. In other words, the creative reasoning approach helps students think mathematically adaptively, a skill that is highly needed in the era of competency-based learning (Afriansyah et al., 2024; Birgili, 2015; Cho & Lee, 2017; Maharani et al., 2021). Overall, these findings confirm that the creative mathematical reasoning approach is not only statistically effective but also pedagogically and functionally effective in improving students' literacy and numeracy through more active, meaningful, and contextual learning experiences (Anggraini et al., 2019; Clarke & Roche, 2018; Damayanti & Afriansyah, 2018; Delyana et al., 2022).

Observations of the learning process reveal that students who follow the creative mathematical reasoning (CMR) approach exhibit more active, creative, and reflective learning behaviors than students in the control class. This finding is consistent with prior research, which emphasizes that CMR encourages student participation, active engagement, and reflective reasoning (Lithner, 2008; Hidayat, Wahyudin, & Prabawanto, 2018).

The first aspect is that students are more active in discussing and conveying ideas. Their participation in discussions and sharing of ideas demonstrates that students feel directly involved in the learning process. This reflects the existence of a dialogic and constructive learning environment, where students are not only recipients of information but also active participants in the construction of knowledge. Discussions triggered by open-ended questions and contextual numeracy problems encourage students to think critically and explain the reasoning behind their problem-solving (Yunita, Santoso, & Pramudya, 2023).

The second aspect is the demonstration of various creative strategies in solving contextual numeracy problems. Students are not fixated on one solution method, but can explore diverse strategies according to the context of the problem. This indicates the development of divergent thinking skills and cognitive flexibility—two main aspects of creative mathematical reasoning (Cansoy & Türkoğlu, 2017; Doleck et al., 2017; Tee, Leong, & Lee, 2018). Within the framework of numeracy literacy, this ability is very important because it reflects an understanding that is not merely procedural, but conceptual and applicable (Dwyer, Hogan, & Stewart, 2017; Mlotshwa, Mhlolo, & Schafer, 2020). Creativity in choosing solution strategies also shows that students are beginning to realize that there are multiple logical paths to a solution, which strengthens higher-order thinking skills (Leikin, Bicer, & Levav-Waynberg, 2022).

The third aspect is that students tend to be more confident and think reflectively when solving problems. Increased self-confidence in mathematics learning is often an indicator of the success of a participatory approach that does not punish mistakes. Creative reasoning provides a safe space for students to try, fail, revise, and learn from the process—a reflective cycle that is essential in problem solving (Ijirana & Mansyur, 2020; Kholid, Sugandi, & Amelia, 2021). The ability to think reflectively shows that students not only focus on the result, but also evaluate the process, strategies, and decisions they make. This aligns strongly with the essence of numeracy literacy in the *Merdeka Curriculum*, namely, fostering the ability to use mathematics consciously, critically, and contextually.

Literacy, numeracy, and mathematical reasoning are fundamentally interconnected, as both serve as essential components in developing higher-order cognitive abilities in mathematics education. Literacy and numeracy refer to the ability to use, interpret, and communicate mathematical information effectively in real-world contexts, while mathematical reasoning is the process of drawing logical conclusions, justifying procedures, and constructing arguments based on mathematical principles (Lozano-Arias et al., 2021; Yunita et al., 2023). The results of this study, which show significant improvements in the experimental group using the *Creative Mathematical Reasoning* (CMR) approach, reaffirm the close relationship between reasoning and numeracy skills.

The findings are consistent with previous studies that emphasize the role of reasoning in enhancing literacy and numeracy. For example, Lithner (2008) demonstrated that creative reasoning encourages students to justify solutions and move beyond rote computation, which directly supports the development of numeracy competencies. Similarly, Leikin, Bicer, and Levav-Waynberg (2022) highlighted that mathematical creativity and reasoning enable students to generate multiple strategies, reflect on their thinking, and apply knowledge in authentic contexts—skills that align with the goals of literacy and numeracy.

In line with these results, Palayukan et al. (2023) argued that engaging students in numeracy-rich tasks—such as interpreting data, budgeting, or contextual problem-solving—stimulates mathematical reasoning, as students are challenged to make decisions, justify strategies, and evaluate outcomes. Thus, the improvement observed in the experimental group of this study aligns with earlier evidence that emphasizes the need for reasoning to give numeracy meaning and applicability.

However, some prior research reported differing emphases. For instance, Mlotshwa, Mhlolo, and Schafer (2020) found that while reasoning improved students' performance in critical numeracy tasks, not all students transferred reasoning skills effectively into real-life applications, suggesting that contextualization alone may not be sufficient. Likewise, Tee, Leong, and Lee (2018) found that divergent thinking in problem solving varied significantly depending on student learning styles, indicating that the benefits of reasoning-based approaches may differ according to individual learner characteristics. These findings suggest that while reasoning is crucial, literacy and numeracy outcomes may still depend on other mediating factors, such as student motivation, prior knowledge, and classroom environment.

Taken together, the present study strengthens the body of evidence supporting the integration of reasoning-focused approaches in numeracy instruction. It shows that creative mathematical reasoning not only enhances students' problem-solving skills but also promotes more active, creative, and reflective behaviors in mathematics learning. This suggests that literacy, numeracy, and mathematical reasoning should not be treated as separate domains but as mutually reinforcing constructs that must be cultivated simultaneously to prepare students for complex academic and societal challenges.

4. CONCLUSION

The descriptive analysis revealed that the experimental class taught using the Creative Mathematical Reasoning (CMR) approach achieved a higher post-test mean score ($M = 78.9$; $SD = 10.53$) compared to the control class ($M = 67.8$; $SD = 5.30$). This indicates that CMR-based learning more effectively enhanced students' numeracy literacy. The paired t-test revealed a significant improvement in scores between the pre-test and post-test in both groups. However, the increase was greater in the experimental class ($t = 12.45$; $p < 0.001$) compared to the control class ($t = 9.86$; $p < 0.001$). The independent t-test revealed a significant difference between the post-test scores of the experimental and control classes ($t = 3.21$; $p = 0.002$, $p < 0.05$). This confirms that the application of CMR had a positive effect on students' learning achievement. The findings highlight that implementing CMR encouraged students to be more active in expressing ideas, employ diverse problem-solving strategies, and think more reflectively when solving numeracy tasks. Consequently, the numeracy literacy developed was not only procedural but also conceptual and applicable to real contexts. In summary, the application of Creative

Mathematical Reasoning proved effective in improving students' numeracy literacy. This approach plays a crucial role in developing higher-order thinking skills required in the context of the Merdeka Curriculum and preparing students for complex problem-solving in academic and real-life situations.

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