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ENHANCING MATHEMATICAL CREATIVE THINKING ABILITY: EXPERIMENTATION WITH REALISTIC MATHEMATICS EDUCATION BY EMBEDDING ICE BREAKING IN JUNIOR HIGH SCHOOL

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Abstract: *The effectiveness of Realistic Mathematics Education (RME) in improving students' mathematical abilities has been examined through various research. Meanwhile, the use of ice-breaking (Ib), considered by experts and educational researchers as a highly beneficial tactic for improving learning effectiveness, had yet to be fully explored in the context of integration with RME. The study aimed to examine the effectiveness of Ib-RME (RME integrating Ib) in enhancing students' mathematical creative thinking abilities (MCTA) at SMPN 14 Tarakan, Indonesia. Involving 64 seventh-grade students in a quasi-experimental design, the experimental group adopted the Ib-RME approach. In contrast, the control group followed the conventional teaching method employed by mathematics teachers in the class, including ice-breaking activities as normally implemented in the classroom setting. Data analysis using t-tests revealed a significant improvement in MCTA in the Ib-RME group, confirming the effectiveness of this approach. The research noted that conventional teaching also enhanced MCTA, although to a lesser extent than Ib-RME. These findings contributed to understanding the potential integration between RME and Ib in improving Mathematics learning outcomes, particularly in developing MCTA. The implications could serve as a basis for the development of innovative and effective teaching approaches in the mathematics education.*

Keywords*: conventional learning, ice-breaking, mathematical creative thinking ability, realistic mathematics education, school mathematics.*

INTRODUCTION

Creativity is one of the most potent human behaviors, and it serves as a hallmark of societal progress and individual success in everyday life (Agnoli et al., 2023). Creativity is closely related to the world of art and the creation of products and is also closely associated with science, technology, innovative thinking, and problem-solving (Henriksen et al., 2018). Creativity is essential; individuals can tap into their potential to use their imagination, express themselves, and make original and valuable life choices (Nikolopoulou, 2018). Creativity in education aims to mold students into independent, resourceful, and confident individuals when facing various challenges (Guilford, 1967).

Creativity has always been important in mathematics (Schindler &

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Lilienthal, 2020). Creativity and intelligence are considered the most essential and distinctive constructs for humans in acquiring knowledge, producing knowledge, and knowledge-based behavior (Corazza & Lubart, 2021). Meanwhile, creative thinking ability is the capacity to generate new and different ideas from others (Marni & Pasaribu, 2021). Creative thinking ability is one of the skills required in the 21st century. Developing creative thinking skills has become a focus in education, including mathematics education. Students are expected to possess logical, analytical, systematic, critical, and creative thinking abilities and the ability to collaborate (Adiastuty et al., 2021).

According to the information above, a skill known as Mathematical Creative Thinking Ability (MCTA) is also promoted in mathematics. MCTA is the ability of students to respond to an open task in the context of mathematical learning (fluency), demonstrate various types of ideas and switch between those ideas (flexibility), and discover ideas beyond those previously generated (originality) (Bruhn & Lüken, 2023). According to Bicer et al. (2020), MCTA is the ability to generate new mathematical ideas or concepts. These ideas in MCTA may be new to an individual but not necessarily new to others by understanding and selecting acceptable mathematical models. MCTA is one of the skills that students must possess in the study of mathematics, as through MCTA, students will develop sensitivity to arising problems, identify these problems, and ultimately generate solutions to resolve them (Suciati et al., 2021). MCTA can also be understood as one of the determinants of whether students have comprehended the mathematical concepts provided during the learning process (Siahaan, 2019).

As previously stated, MCTA is a crucial skill needed to keep up with the rapid advancements in science, technology, engineering, arts, and mathematics. Education plays a significant role in nurturing students' MCTA, as this ability is essential for generating new knowledge (Henriksen et al., 2018). Paradoxically, the MCTA of students' in Indonesia is still relatively low (Yuniarti et al., 2021). On average, students can only solve simple problems, and they are not accustomed to solving non-routine problems or problems that require high-order thinking skills (HOTS), such as creative thinking (Sahliawati & Nurlaelah, 2020). Most students are inclined towards convergent thinking, where they rely on procedural thinking, following problem-solving steps provided by teachers (Nasution et al., 2021).

Surveys indicate that mathematical problems demanding MCTA from Indonesian students fall below the international average (Ramadhani & Caswita, 2017). In line with this, research results show that students have not yet well-mastered MCTA indicators, which undoubtedly contributes to their low MCTA levels (Nuranggraeni et al., 2020). According to Nurjanah et al. (2019), students often need more time to come to conclusions, hindering the development of MCTA in problem-solving and the generation of new ideas. A low MCTA in mathematics can also lead to students developing a negative attitude toward learning mathematics, resulting in their dislike for the subject (Adiastuty et al., 2021).

In light of the information mentioned above, a preliminary study at SMP Negeri 14 Tarakan, one of the junior high schools in North Kalimantan, Indonesia, revealed that students' MCTA remained relatively low. Through interviews with teachers, it became apparent that MCTA among students was a

concern. A mathematics teacher from the school remarked:

> *The students' creativity* (= MCTA) *condition is low because their fundamental mathematical abilities are also low* [...]. *When I ask them to solve mathematical problems in multiple ways, on average, students face difficulties, so they sometimes lose interest and tend to give up when I present such problems.*

The same sentiment was echoed during interviews with students, who expressed disinterest in working on problems that require more than one approach and are unfamiliar with open-ended questions. For example, a student interview stated:

> *I am not interested in solving problems with multiple solutions, Miss, because I find it difficult, so I am reluctant to try* [...]. *Besides, teachers rarely give such problems, so I am not accustomed to them.*

The researcher also conducted tests to assess students' MCTA, and based on the test results, the average score for students was 39.30. Examples of students' work can be seen in Figure 2, and the questions can be viewed in Figure 1.

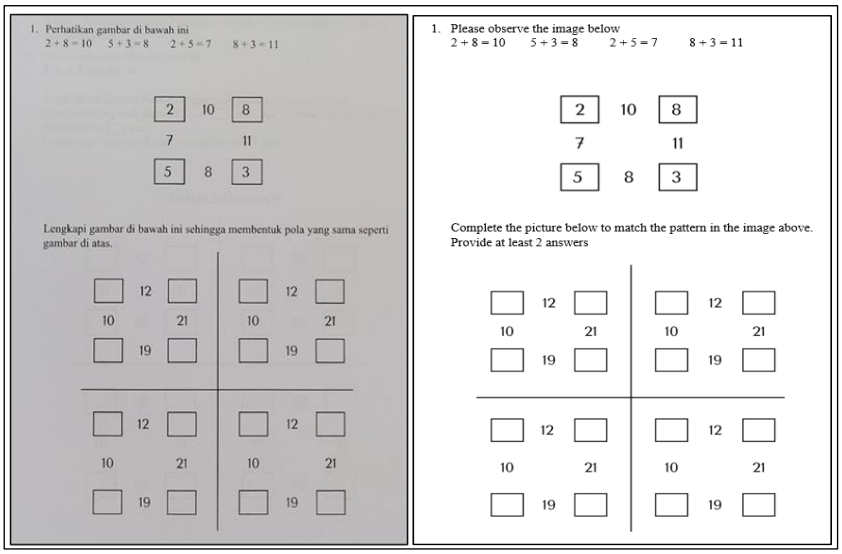


Figure 1 An Example Question from Preliminary Studies

In the question above, students have been given an example of how to complete the given image in a manner that replicates the same pattern as the provided example. However, one of the student response sheets is as follows:

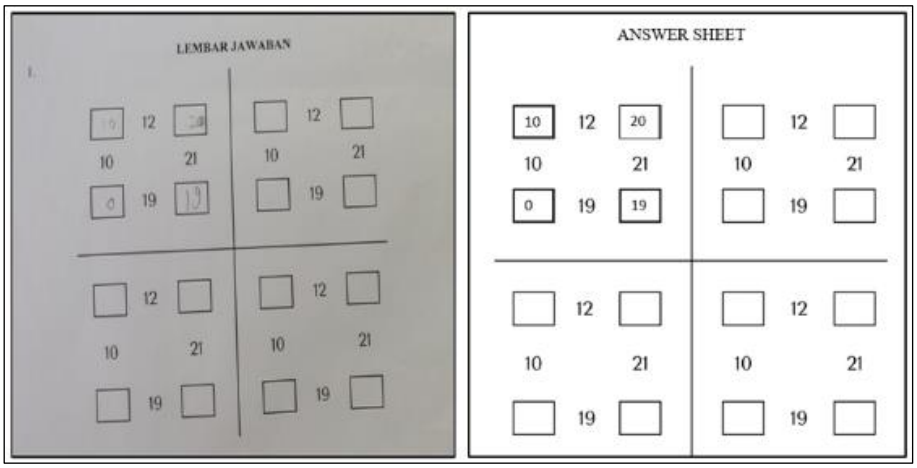


Figure 2 Student's Response

Based on the response above, the student needed help comprehending what was instructed in the question. In the question, students were asked to complete the pattern by finding pairs of numbers that, when added together, would result in those numbers. In the given response, the student could only provide one answer, and there was an error in the calculation. The student wrote $10 + 20 = 12$ and $20 + 19 = 21$, which is an incorrect addition. Based on the results of interviews and tests conducted to assess students' MCTA, it can be concluded that a significant portion of MCTA among students at SMP Negeri 14 Tarakan is considered low.

The current state of teaching and learning in Indonesia must provide a sufficiently conducive environment for nurturing students' creativity and performance in mathematics (Ndiung et al., 2021). One of the factors that can aid in the development of mathematical thinking and students' mathematics learning outcomes is the instructional model teachers use (Zubaidah et al., 2017). At the same time, conventional learning is the most widely employed model by teachers, from elementary to secondary levels, to enhance students' mathematics learning abilities (Juniawan et al., 2023). Using conventional learning models often results in monotonous classroom instruction, leading to student boredom, disinterest in learning, and a weaker understanding of the material taught (Palinussa, 2020). Most negative responses arise from students' mathematics education experiences that employ conventional models (Bray & Tangney, 2016). Palinussa's research (2020) states that realistic mathematics education (RME) outperforms conventional teacher-centered instructional models.

Low MCTA needs to be anticipated or improved. RME is one instructional model oriented towards real-life experiences to enhance students' MCTA (Iskandar & Juandi, 2022). RME is a mathematics teaching model, and one of its approaches involves introducing the context of the 'real world,' introduced by mathematicians from the Freudenthal Institute at Utrecht University in the Netherlands in 1973 (Heuvel-Panhuizen & Drijvers, 2020). RME was developed based on the ideas of Hans Freudenthal, who believed that mathematics is a human activity that should be connected and relevant to students' everyday lives (Hadi, 2017). Mathematics as a human activity means that students must rediscover

mathematical ideas and concepts with the guidance of a teacher (Ardi, 2021).

According to Heuvel-Panhuizen and Drijvers (2020), RME is an instructional model that emphasizes realistic problems in the learning process to gradually develop students' mathematical concepts into a more formal and specific form. These realistic problems have a broad meaning: problems that students can envision. The problems presented to students are not only derived from everyday problems but can also originate from problems that may not occur in daily life but are confirmed in the students' minds. The uniqueness of RME lies in presenting rich and realistic situations in the learning process (Juandi et al., 2022). It allows students to explore their prior knowledge, gradually leading to a more formal understanding (Heuvel-Panhuizen, 2020).

RME can optimize students' MCTA because it is grounded in practical issues from everyday life that hold personal significance for students (Asmara et al., 2022). According to Melawati (2020), RME can facilitate students' understanding of mathematical problems and enhance their mathematical communication skills. Learning through RME allows students to apply mathematical concepts to solving real-life problems, honing their mathematical problem-solving abilities (Asih, 2019). Furthermore, Marni and Pasaribu (2021) state that the RME instructional model can also boost students' interest in learning as it directly relates to their experiences, creating distinct memories of the material being studied (Marni & Pasaribu, 2021).

Integrating ice-breaking activities into teaching is instrumental in cultivating a creative environment, particularly concerning MCTA. A body of research underscores the crucial role of these activities in establishing a positive and engaging learning atmosphere in the mathematics classroom (Cohen, 2014; Kurniasih & Lenaldi, 2018; Parlina et al., 2023; Sasan et al., 2023). Icebreakers contribute to developing overall social and mathematical skills and enhance the learning process's effectiveness and enjoyment. They create a positive atmosphere by fostering comfort, building rapport among peers, and nurturing a supportive learning community—essential for collaborative and interactive learning experiences.

Furthermore, ice-breaking activities extend beyond their social benefits. They are valuable tools for demystifying mathematics, often perceived as challenging and anxiety-inducing (Frankel & Smith, 2022). Breaking down initial barriers and encouraging active engagement is crucial in promoting a positive mindset toward the subject, thus fostering student motivation and openness to the learning process. Moreover, their intentional design can indirectly involve mathematical thinking, preparing students for more formal discussions and problem-solving scenarios, ultimately contributing to creating a conducive and enriching learning environment (Cohen, 2014).

Low MCTA must be enhanced, and students should become accustomed to divergent thinking. Students accustomed to simply convergent thinking (thinking towards a single, fixed answer) will encounter difficulties when faced with real problems (Asmara et al., 2022). The learning process should focus on more than just basic skills dominated by routine exercises solved through convergent thinking, memorization, and repeating examples provided by the teacher (Nasution et al., 2021). Students who excel in divergent thinking can generate many different and original responses to open-ended questions, think of multiple solutions, and tend not to readily accept a

single solution or answer (Luria et al., 2017). MCTA plays a crucial role in the advanced mathematical thinking cycle, helping to make reasonable conjectures to develop mathematical theories and generate new mathematical knowledge (Nadjafikhah et al., 2012). MCTA is essential for the development of high-order mathematical thinking. Moreover, MCTA also plays a critical role in students' success in mathematics learning (Marni & Pasaribu, 2021).

Creativity in education strives to mold students into independent, imaginative, and confident problem solvers, representing the cornerstone of education's problem-solving capacity (Guilford, 1967). As previously mentioned, one way to address low MCTA is through using the RME. As previously noted, one approach to address low MCTA is using RME. Furthermore, integrating ice-breaking (IC) into the learning approach proves beneficial in cultivating a creative environment. Additionally, the previous teacher instructing the student participants in this study frequently employed ice-breaking during direct instruction or conventional teaching to enhance the effectiveness and enjoyment and to keep students engaged and alert. It is important to highlight that teaching and learning activities at this junior high school commence in the afternoon, from 01:00 PM to 05:00 PM. In light of the study's background, our research objectives are twofold: first, to ascertain the difference in MCTA between students taught using RME by embedding ice breaking (Ib-RME) and those taught through conventional teaching, which also incorporates ice breaking, in the seventh grade at SMP Negeri 14 Tarakan; and second, to assess the improvement in MCTA among students taught with RME.

METHOD

The method employed in this research is a quasi-experimental research method. The research design utilized a non-equivalent control group design. The population used in this study consists of all the 7th-grade students at SMP Negeri 14 Tarakan (one of the public junior high schools in North Kalimantan Province, in Indonesia). Sampling was carried out using a simple cluster sampling technique. The selected class for the experimental group is Class 7.2, while Class 7.1 is the control group (see learning scenario in Appendix 1 and Appendix 2). The selection was made through a lottery that included classes 7.1, 7.2, and 7.3. Class 7.2 was chosen as the experimental group in the first draw, and in the second draw, Class 7.1 was selected as the control group. In this research, the MCTA indicators are used as follows:

Table 1 Mathematical Creative Thinking Ability Indicators

Aspect	Indicator
Fluency	The student's ability to generate accurate and complete mathematical problem-solving responses. In this study, students are considered proficient in solving mathematics problems when they can write at least two complete answers to each math question during the MCTA test.
Flexibility	The student's capacity to adapt their thought process when encountering challenges in solving mathematical problems is a critical factor in achieving successful solutions. In the scope of this study, students are considered adept in tackling math problems if they can provide at least two comprehensive and accurate answers, spanning different categories, for each question during the MCTA test.
Originality	The student's ability to generate unfamiliar or unique solutions. In this study, students are considered capable of solving issues initially when they can write at least two complete solutions, each unique or unfamiliar, compared to other students' answers during the MCTA test.

This research employed a non-equivalent control group design; thus, the effectiveness of RME embedding ice breaking (Ib-RME) in enhancing MCTA was asserted based on two conditions: 1) the average pre-test MCTA scores of the experimental group (students who underwent Ib-RME learning) were equal to the control group (students who underwent conventional learning, and 2) the average post-test MCTA scores of the experimental group higher than the control group. In light of those conditions, we proposed the following hypotheses as part of the research method:

(1) For μ_1, the mean MCTA of students in the experimental group during the pretest, and μ_3, the mean MCTA of students in the control group during the pretest, the hypotheses were formulated as follows:

Null Hypothesis:
$\mu_1 = \mu_3 \leftrightarrow \mu_1 - \mu_3 = 0$
Interpretation: "There is no significant difference in MCTA between the experimental and control group during the pretest."

Alternative Hypothesis:
$\mu_1 \neq \mu_3 \leftrightarrow \mu_1 - \mu_3 \neq 0$
Interpretation: "There is a significant difference in MCTA between the experimental and control group during the pretest."

(2) For μ_2, the mean MCTA of students in the experimental group during the posttest, and μ_4, the mean MCTA of students in the control group during the posttest, the hypotheses were formulated as follows:

Null Hypothesis:
$\mu_2 = \mu_4 \leftrightarrow \mu_2 - \mu_4 = 0$
Interpretation: "There is no difference in MCTA between the experimental and control group."

Alternative Hypothesis:
$\mu_2 \neq \mu_4 \leftrightarrow \mu_2 - \mu_4 \neq 0$
Interpretation: "There is a difference in MCTA between the experimental and control group."

In summary, the research aimed to investigate whether Ib-RME enhances MCTA. The null hypothesis proposed that there would be no mean difference in MCTA

between the experimental and control groups before the intervention. Conversely, the alternative hypotheses proposed significant differences in MCTA between the two cohorts' means after implementing Ib-RME, with the experimental group's mean greater than the control group's ($\mu_1 = \mu_3$ and $\mu_2 > \mu_4$). These hypotheses were the cornerstone for examining the intervention's effects by analyzing MCTA mean differences across the groups post-intervention.

RESULTS AND DISCUSSION

Based on the pre-test and post-test results administered to the experimental and control groups, the descriptive analysis results for the pre-test and post-test, with the assistance of Statistical Program for Social Science (SPSS) 27 for Windows, for both the experimental and control groups were as follows:

Table 2 Mathematical Creative Thinking Ability Based on Test Result

Learning Model	Data	N	$\bar{X}$	SD
Realistic Mathematics Education-Ice Breaking	Pre-Test	32	28.75	7.750
	Post-Test	32	76.63	8.071
Conventional Teaching	Pre-Test	32	28.69	6.537
	Post-Test	32	63.44	10.476

Descriptively, there is an improvement in MCTA both after Ib-RME and conventional teaching. In this context, a more significant improvement in MCTA is achieved when learning is conducted using the RME approach. Inferential analysis was also conducted to strengthen this analysis, which will be discussed in the next section. Here is one example of a fraction question used to measure students' MCTA with the Ib-RME instructional model.

Complete the fractions below and arrange the numbers from smallest to largest. Provide at least 2 answers!

$$\frac{a}{6}; \frac{b}{3}; \frac{c}{2}; \frac{d}{5}$$

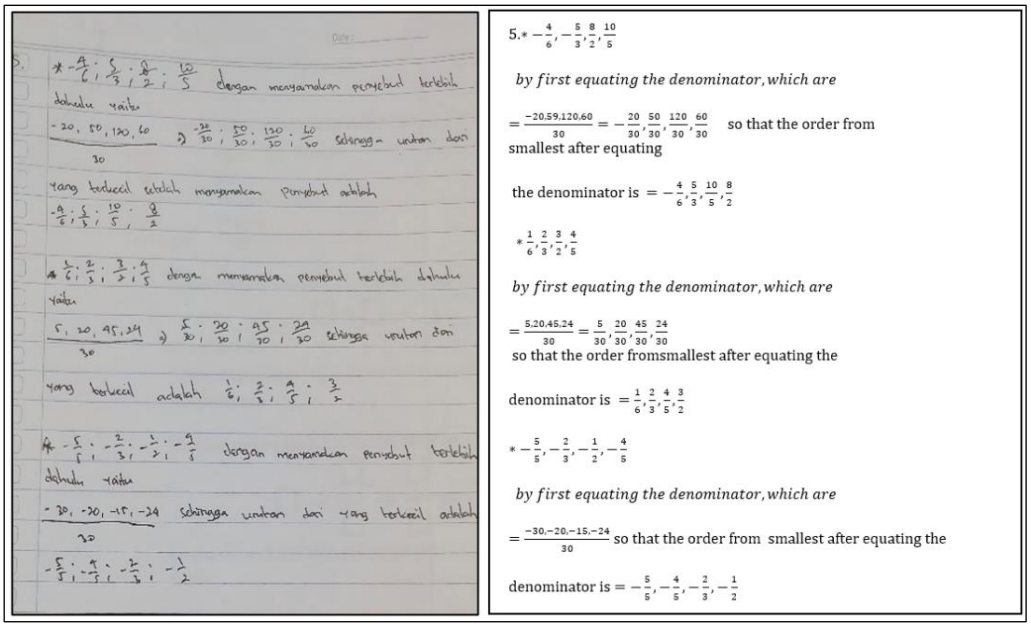
Figure 3 Question Number 3 (Post-Test Question Example)

Students solved the problem in Figure 3 based on the MCTA indicator. Below is an example of an answer from the experimental group. Figure 4 indicates that the response from the student with the code S.72.03 meets all the MCTA indicators. The student solved the mathematics problem smoothly by providing two complete answers. The student demonstrated fluency in solving the mathematics problem by providing two complete and correct answers. Additionally, the student exhibited originality by providing at least two complete answers, each unique or unfamiliar compared to other students' answers.

Figure 5 indicates that the response from the student with the code S.71.28 has yet to meet the MCTA indicators effectively. The student solved the problem by providing two answers but did not write them com-

pletely, could not provide correct answers, and wrote answers that were familiar compared to other student's responses.

Furthermore, the results from the experimental and control groups based on the MCTA aspects were as follows:



5.* $-\frac{4}{6}, -\frac{5}{3}, \frac{8}{2}, \frac{10}{5}$

by first equating the denominator, which are

$= \frac{-20.59.120.60}{30} = -\frac{20}{30}, \frac{50}{30}, \frac{120}{30}, \frac{60}{30}$ so that the order from smallest after equating

the denominator is $= -\frac{4}{6}, \frac{5}{3}, \frac{10}{5}, \frac{8}{2}$

* $\frac{1}{6}, \frac{2}{3}, \frac{3}{2}, \frac{4}{5}$

by first equating the denominator, which are

$= \frac{5.20.45.24}{30} = \frac{5}{30}, \frac{20}{30}, \frac{45}{30}, \frac{24}{30}$ so that the order fromsmallest after equating the

denominator is $= \frac{1}{6}, \frac{2}{3}, \frac{4}{5}, \frac{3}{2}$

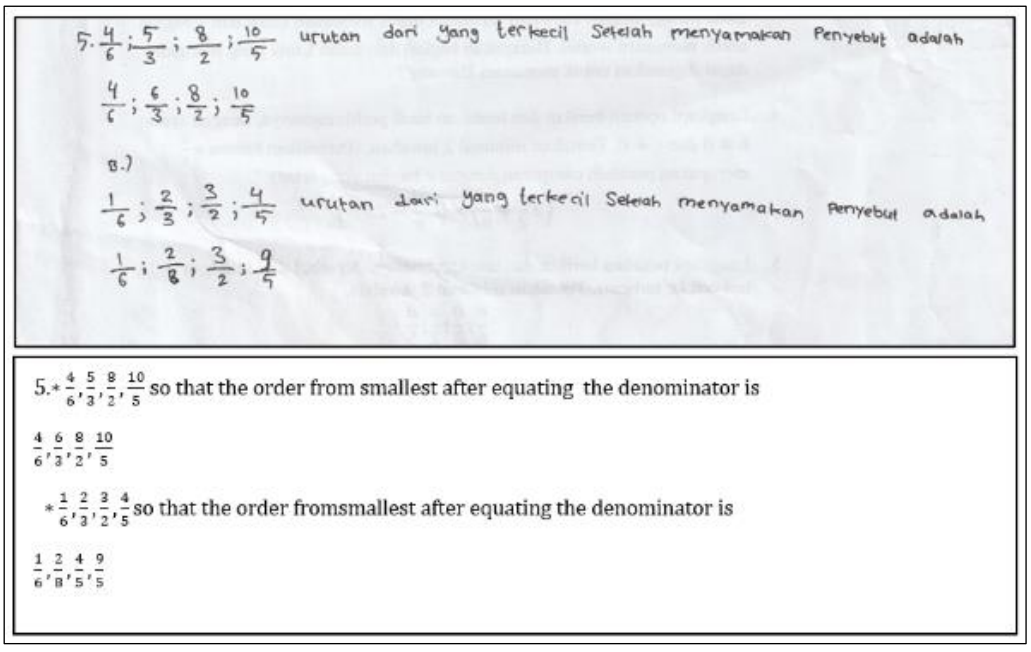
* $-\frac{5}{5}, -\frac{2}{3}, -\frac{1}{2}, -\frac{4}{5}$

by first equating the denominator, which are

$= \frac{-30.-20.-15.-24}{30}$ so that the order from smallest after equating the

denominator is $= -\frac{5}{5}, -\frac{4}{5}, -\frac{2}{3}, -\frac{1}{2}$

Figure 4 Example of Student's Answer in The Experimental Class



5. $\frac{4}{6}; \frac{5}{3}; \frac{8}{2}; \frac{10}{5}$ urutan dari yang terkecil Setelah menyamakan Penyebut adalah

$\frac{4}{6}; \frac{6}{3}; \frac{8}{2}; \frac{10}{5}$

B.)

$\frac{1}{6}; \frac{2}{3}; \frac{3}{2}; \frac{4}{5}$ urutan dari yang terkecil Setelah menyamakan Penyebut adalah

$\frac{1}{6}; \frac{2}{8}; \frac{3}{2}; \frac{9}{5}$

5.* $\frac{4}{6}, \frac{5}{3}, \frac{8}{2}, \frac{10}{5}$ so that the order from smallest after equating the denominator is

$\frac{4}{6}, \frac{6}{3}, \frac{8}{2}, \frac{10}{5}$

* $\frac{1}{6}, \frac{2}{3}, \frac{3}{2}, \frac{4}{5}$ so that the order fromsmallest after equating the denominator is

$\frac{1}{6}, \frac{2}{8}, \frac{4}{5}, \frac{9}{5}$

Figure 5 Example of Student's Answer in The Control Class

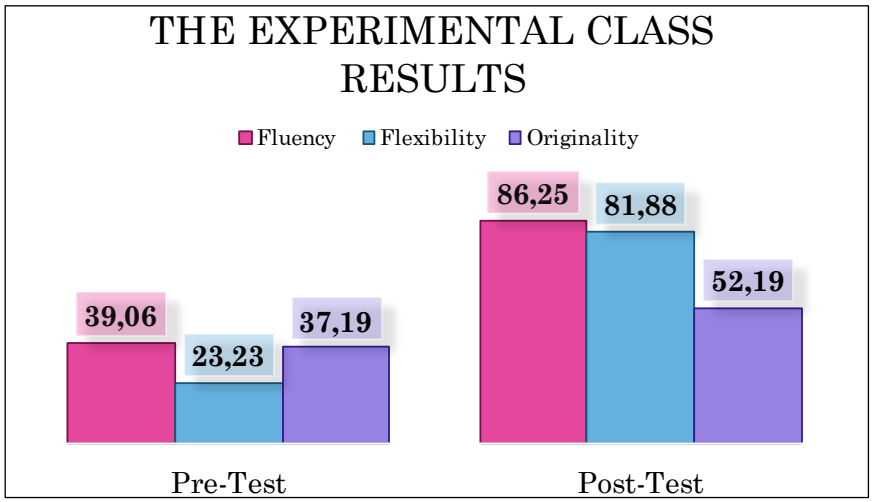


Figure 6 Experimental Class Results

In the experimental group, the pre-test and post-test results yielded different averages for each aspect. The difference in terms of fluency was 47.19, in terms of flexibility was 58.65, and in terms of authenticity was 15. There was a significant improvement in fluency and flexibility when comparing the pre-test and post-test results.

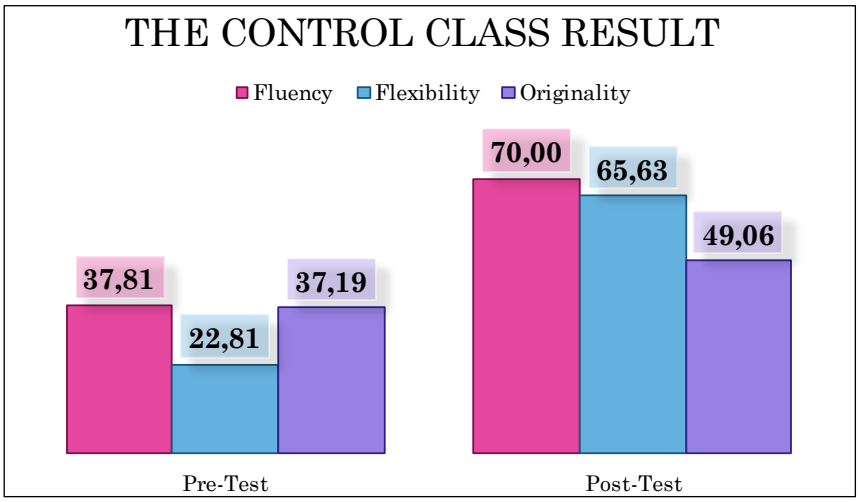


Figure 7 Control Class Results

In the control group, the pre-test and post-test results yielded different averages for each aspect. The difference in terms of fluency was 32.19, in terms of flexibility was 42.82, and in terms of authenticity was 11.87. There was a significant improvement in fluency and flexibility, although not as substantial as in the experimental group. Further analysis to determine whether these differences are statistically significant or not will be conducted using an independent sample t-test. After conducting normality and homogeneity tests, the data was normally distributed and homogeneous. Subsequently, further analysis was conducted using an independent sample t-test.

Table 3 Independent Sample T-Test Results for Mathematical Creative Thinking Ability

Independent Sample T-Test								
Levene's test for equality of variances		T-test for equality of means						
F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std.Error Difference	95% Conf Interval of The Difference	
							Lower	Upper
1.567	0.215	5.641	62	0.001	13.188	2.338	8.514	17.861

In Table 3, the Levene test results $(F = 1.567, p = 0.215)$ indicate that equal variances are assumed, as $p > 0.05$, confirming homogeneous variances in both populations. By employing the assumption of equal variances, the independent sample t-test yielded a significant t-value of 5.641 $(p = 0.001)$. This result leads to the rejection of the null hypothesis (H_0). Furthermore, the calculated t-value $(t_{calculated} = 5.641)$ surpasses the critical t-value $(t_{table} = 1.960)$, emphasizing a highly significant difference between the experimental and control groups. With a significance level $(sig)\ of\ 0.001$, which is less than the customary threshold of 0.05, we also reject H_0. These findings indicate a noteworthy difference in MCTA between the two groups, supporting the assertion that Ib-RME enhances MCTA.

Table 4 Group Statistics for Mathematical Creative Thinking Ability

Group Statistics				
Class	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Post-Test Experiment	32	76.63	8.071	1.427
Post-Test Control	32	63.44	10.476	1.852

As shown in Table 4 above, the average post-test score in the experimental group is higher than that in the control group. Overall, the results of MCTA in the experimental group are better than those in the control group—the improvement in MCTA after using Ib-RME in teaching students about fractions is significant. The increase in MCTA is a condition that indicates an increase in MCTA scores based on test results. This study used a non-equivalent control group design. The statement that Ib-RME enhances MCTA refers to two conditions: 1) the average pre-test MCTA in both groups is the same, and 2) the average post-test results of MCTA in the experimental group are higher than in the control group. It can be concluded that there is a significant difference in MCTA between the experimental group and the control group, and RME can enhance MCTA.

Based on the theory proposed by Freudenthal, the main idea in RME is reinvention. Freudenthal interprets reinvention as steps in the learning process through reinvention. Students are the inventors, and teachers are the guides in this process—the role of students as inventors and teachers as guides goes hand in hand during problem-solving. In guiding rediscovery, a balance must be struck between the freedom to discover and guidance, meaning students can solve problems independently and receive guidance from the teacher (Jahnke et al., 2022). When implementing Ib-RME, the

researcher (author 1), who also acts as the teacher, realizes this concept. According to Freudenthal, students should be active participants in the learning process, not just recipients of mathematics that can be directly applied. In RME, students are presented with problems that can be solved using various mathematical tools and knowledge. Through problem-solving and problem presentation, teachers can enhance students' capacities related to the core of creativity: fluency, flexibility, and originality. The results of this study align with these ideas.

As presented in Table 3, this study yields results indicating a significant difference in students' MCTA between the experimental and control groups, where RME can enhance students' MCTA. The significant difference in post-test MCTA outcomes between the experimental and control groups is attributed to the instructional model variance. Learning in the experimental group emphasizes a learning process that presents mathematics problems students can envision. The learning process is student-centered rather than teacher-centered, demanding active student participation in the learning process. In RME, students can also engage in discussions with peers in small groups and class discussions. According to Heuvel-Panhuizen and Drijvers (2020), mathematics learning is not solely an individual activity but a social one; in RME, students are encouraged to share their strategies and findings with others.

When implementing RME, the math problems presented to students are realistic and can be vividly imagined in students' minds, meaning these problems are realistic to the students. In contrast, learning in the control group is teacher-centered, with students primarily listening to and taking notes on the explained material. Activities that do not demand student engagement occasionally make the class boring and monotonous. Traditional teaching methods for mathematics need to be sufficiently robust to strengthen students' problem-solving skills; hence, they do not assist students in developing other competencies and applications in mathematics (Schoenfeld, 1987). The results of this study indicate a mismatch with these notions, as MCTA in the control group also improved but not to a higher degree than in the experimental group. Traditional teaching emphasizes mechanistic learning, memorization of solutions, and mathematical operations (Riyanto et al., 2018).

The results of this study, in line with the findings of Wahyuni and Pasaribu (2022), indicate that RME can facilitate and enhance students' creative thinking abilities in solving and comprehending problems in the taught material. Consistent with this, the research by Asmara et al. (2022) states that learning with RME can improve students' MCTA. This finding is further supported by the findings of Iskandar and Juandi (2022), indicating that RME positively impacts students' MCTA. The improvement in MCTA after learning with RME positively impacts students in the fraction topic. In line with this, fostering creativity by applying RME can nurture logical, critical, and creative thinking (Sitorus & Masrayati, 2016). RME can construct students' cognitive mathematical knowledge in each stage of the creative thinking process. According to Heuvel-Panhuizen and Drijvers (2020), RME is a teaching model that highlights realistic problems in the learning process to gradually develop students' mathematical concepts, making them more formal and specific. In RME, the presentation of contextual problems in learning can stimulate MCTA when students create mathematical models and indepen-

dently solve these problems (Prianto et al., 2016).

In the experimental class, through the presentation of realistic problems, students can solve problems in their way, which brings out different strategies in each student. The freedom granted to students challenges them to tackle the given problems and makes learning more enjoyable because it appears varied to them. Learning that comforts students makes them more creative (Mastria et al., 2019). Students are allowed to solve problems according to the schemes in their minds while still adhering to the principles and characteristics of RME (Palinussa et al., 2021).

Mathematical tasks do not necessarily have to refer to applications found in the real world but can be 'real mathematics,' meaning that students build upon their previous mathematical knowledge (Fredriksen, 2021). The term ‘real’ refers to problems presented to students that should be problems they can imagine, implying that the context does not have to be limited to real-world situations (Panhuizen, 2003). In RME, students can discover concepts in the given material and become more actively engaged in learning. This finding aligns with the research by Laurens et al. (2018), which suggests that RME trains students to discover concepts and encourages active student involvement in learning that demands initiative in solving realistic contextual problems.

Based on the results of this research, it is evident that there is a significant difference in MCTA between the experimental and control classes, with RME enhancing students' MCTA. Due to these research findings, there are implications to consider in improving students' MCTA. Teachers can implement RME to enhance students' MCTA. Furthermore, learning using RME transforms initially passive students as learning shifts from teacher-centered to more active. Learning becomes more enjoyable and communicative because students can explore learning topics freely. This finding aligns with Frediksen's (2021) view that in RME, the teacher-centered model of learning transitions into a model that allows students more time in class to explore learning topics in greater depth, creating more prosperous learning opportunities.

In RME, students are allowed to discuss strategies for solving problems with their peers. Communication among students improves and becomes more meaningful. In line with Hirza et al. (2014), during every RME activity, students are given the freedom to discuss strategies for solving problems provided by the teacher, and in doing so, social interaction within the classroom becomes an essential part of the class's overall performance. RME trains students to discover concepts, providing them with more opportunities to actively participate in learning through understanding contextual problems, discussing issues, and finding answers. Students are granted the freedom to think and engage in discussions, and they are encouraged to share ideas and opinions with their peers, especially in discovering mathematical concepts and building their knowledge. Students can also conclude from what they have learned, thereby enhancing their cognitive achievements compared to students who learn through conventional methods (Laurens et al., 2018). With RME, students can derive practical benefits from the material they have studied and apply it in real-life situations (Kusumaningsih et al., 2018).

Through RME, mathematics is presented as a process of reinvention, demanding creativity and students' initiative in thinking (Johar et al., 2021). In the

learning process using RME, students are allowed to reinvent mathematical concepts under the teacher's guidance. The process of reinvention is carried out through horizontal and vertical mathematization, initiated with genuine or authentic problems. These activities enable students to have a deeper understanding of the material presented, which can increase their interest and confidence. If students cannot comprehend a particular topic in their learning, it can affect their confidence in studying subsequent material (Simamora & Khairullah, 2022).

The effectiveness of RME in this experiment is intricately tied to the incorporation of ice-breaking in every session. RME traditionally does not include ice-breaking, but integrating these activities into teaching optimizes RME significantly, fostering a creative environment that empowers students. Notably, studies by Parlina et al. (2023) and Sasan et al. (2023) demonstrate the positive impact of ice-breaking activities. Parlina et al. found that digital ice-breaking in online learning improves students' concentration. At the same time, Sasan et al. study in a senior high school setting revealed a significant increase in students' engagement and participation after icebreaker activities. The qualitative analysis indicated improved community feeling, enhanced classroom atmosphere, and increased willingness to participate. These findings advocate for icebreakers to promote engagement and positive classroom dynamics.

Figure 8 The Implementation of Ice Breaking Using *Mathematical Ludo*

When implementing Ib-RME, ice-breaking activities were only sometimes conducted at the core of the learning session when students looked tired, bored, or sleepy when studying. Sometimes, the activity was carried out during the closing phase of Ib-RME to leave a positive impression on students as the lesson concluded. Ice-breaking was conducted outside the core activity even though the teaching-learning was still enjoyable when students asked for it.

Two ice-breaking activities were conducted during this research, each lasting 5 – 10 minutes: a quiz and mathematical Ludo. When implementing a quiz for fun,

about 5 - 10 minutes, each group was given five mandatory questions, for example, "*Susi has $\frac{3}{4}$ litre of orange juice. Then Susi will pour the orange juice into glasses with each glass containing $\frac{1}{4}$ of a litre. How many glasses can Susi fill with orange juice?*" Subsequently, all groups competed to answer three challenge questions as quickly as possible by pressing a buzzer, for instance, $\left(1\frac{1}{2}+\frac{3}{6}\right)\times\left(\frac{3}{4}-10\%\right)$. Each group had a cheer to excite the game atmosphere.

As an ice-breaking activity, with a duration of 10 – 15 minutes, the *mathematical Ludo* played in this research involves 36 participants divided into four groups. The game begins with a draw to determine the sequence of moves for each group. Like traditional Ludo, players roll dice and move their 'cars' according to the dice roll. The player receives a reward if a car lands on a prize square. When a car stops on a question mark square with an easy or moderate difficulty level, the player receives a pre-prepared mathematical question from an envelope. For example, a question could be, "*Arrange the following fractions from largest to smallest: 1/2, 2/3, and 3/4.*" Meanwhile, if a car stops on a bomb square, the player receives a high-difficulty question, such as, "*Mr. Salim owns a land of 3/5 hectares. He wants to divide the land equally among his four children. How much land does Mr. Salim's children receive if the land is divided equally?*" The winner of the game is the player who reaches the finish square first.

Additionally, Darmayanti et al.'s (2023) study explored the impact of ice-breaking on middle school students' academic motivation, revealing increased interest in learning and strengthened student-instructor relationships. This research adds intriguing aspects to our discussion. Moreover, Pratiwi and Nur (2022) highlighted the positive effect of ice-breaking on elementary school students' motivation to learn mathematics. Together, these studies emphasize the multifaceted benefits of integrating ice-breaking activities into education, supporting our assertion that these activities significantly enhance the effectiveness of the RME model.

Including ice-breaking activities is significant, embedded in both the experimental and control groups. Integrating ice-breaking into this research is motivated by the common practice of teachers incorporating such activities in regular teaching. Introducing icebreakers in the mathematics classroom, particularly at the elementary and junior high levels, is a beneficial pedagogical practice. This belief emphasizes the necessity for further research, particularly in experimental teaching and learning studies, to comprehensively assess the effectiveness of ice-breaking activities. These activities take various formats, including mathematics games and non-mathematics games like stand-up comedy (Kurniasih & Lenaldi, 2018).

This research has several limitations. The study's population comprised only 7th-grade students at SMP Negeri 14 Tarakan, with sampling conducted using a simple cluster sampling technique. Future researchers should broaden the study population for a more comprehensive under-standing. The research design employed was a non-equivalent control group design with group sampling, and it is suggested that future researchers opt for a more robust design, such as a proper experimental design like a pre-test, post-test control group design, or a Solomon four-group design (Creswell & Creswell, 2018). A proper

experimental design, characterized by random sampling and strict control of non-experimental variables, offers the highest level of validity among experimental research designs. Additionally, it is highly recommended for future studies to conduct a mixed-methods approach to thoroughly examine the effects or impact of RME providing ice-breaking activities (Creswell & Creswell, 2018). A proper experimental design, characterized by random sampling and strict control of non-experimental variables, offers the highest level of validity among experimental research designs. Additionally, it is highly recommended that future studies conduct a mixed-methods approach to thoroughly examine the effects or impact of RME providing ice-breaking activities.

CONCLUSION

In conclusion, the research findings and discussions reveal a notable difference in students' MCTA between those taught with Ib-RME and conventional teaching. Although conventional teaching demonstrates some improvement in MCTA based on pre-test and post-test results, it needs to catch up to the impact of Ib-RME. Ib-RME stands out as an alternative and effective method for teaching mathematics, enhancing students' cognitive learning outcomes. The integration of ice-breaking in RME facilitates enhanced MCTA and engages initially passive students, transforming the learning process from teacher-centered to more student-centered. This shift provides a more enjoyable and communicative learning experience as students explore topics freely.

A recommendation for future researchers is to broaden the scope of learning topics within extended class durations. This study was confined to fractions with relatively short class times, limiting the breadth of exploration. Expanding the research population could involve investigating beyond the middle school level, as the current study focused solely on 7th-grade students at SMP Negeri 14 Tarakan, utilizing a simple cluster sampling technique. Additionally, future researchers can enhance the research design by opting for a more robust experimental approach, such as a true experimental design, known for its high validity among various experimental methods. Alternatively, a mixed-methods study could be employed to comprehensively examine the effects or impact of Realistic Mathematics Education incorporating ice-breaking activities.

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