The Effectiveness of the PMR-Based GASING Method in Enhancing Elementary School Students' Critical Thinking Skills

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Abstract
This study examined the effect of the GASING method integrated with Realistic Mathematics Education (RME) on elementary school students' critical thinking skills. The study was motivated by the low level of students' critical thinking in mathematics learning, which is often characterized by procedural and teacher-centered instruction. A quasi-experimental design with a pretest–posttest nonequivalent control group was employed. The participants consisted of 96 fourth-grade students divided into an experimental group (RME-based GASING) and a control group (CTL-based GASING), with 48 students in each group. Data were collected through a mathematical critical thinking skills test administered before and after the intervention and analyzed using descriptive statistics with IBM SPSS at a significance level of α = 0.05. The results showed that students' critical thinking skills improved in both groups. However, the experimental group demonstrated a more equitable distribution of learning outcomes, as indicated by a decrease in the standard deviation from 12.36 to 11.84, while the control group showed an increase from 13.65 to 18.20. These findings suggest that the RME-based GASING method is more effective in improving and equalizing elementary school students' mathematical critical thinking skills than the approach used in the control group.

1. Introduction

Mathematics learning at the elementary school level plays a strategic role in developing students' higher-order thinking skills, particularly mathematical critical thinking. In the context of 21st-century education, critical thinking is an essential competency that enables students to analyze information, evaluate arguments, make logical decisions, and solve complex problems systematically (Putra et al., 2022). In mathematics education, critical thinking is reflected in students' ability to identify problems, develop solution strategies, evaluate mathematical reasoning, and justify conclusions. Therefore, mathematics instruction should move beyond procedural mastery and conceptual memorization toward learning experiences that continuously foster higher-order thinking skills (HOTS).

However, elementary students' mathematical critical thinking skills remain relatively low due to persistent challenges in classroom practices. Mathematics learning in many schools is still dominated by teacher-centered approaches that emphasize formula memorization, procedural exercises, and routine problem-solving activities. Such practices often limit students' opportunities to explore ideas, construct knowledge independently, and engage in reflective thinking processes (Facione, 2020). Consequently, students frequently experience difficulties when solving contextual and non-routine mathematical problems that require analysis, evaluation, and reasoning. This condition reflects a gap between the expected goals of mathematics education and actual instructional implementation, particularly in developing students' conceptual understanding and critical thinking abilities (Pratiwi et al., 2026; Koerunnisa et al., 2025).

One approach considered relevant to addressing these challenges is Realistic Mathematics Education (RME), which emphasizes connecting mathematical concepts with meaningful real-life contexts. Based on Freudenthal's perspective, RME views mathematics as a human activity in which students construct mathematical ideas through exploration, discussion, and reflection. Through contextual problems, students are encouraged to reinvent mathematical concepts and gradually progress from informal strategies toward formal mathematical representations (Cahyaningsih & Nahdi, 2021). This learning process provides opportunities for students to analyze situations, compare solution strategies, and justify mathematical reasoning, thereby supporting the development of critical thinking skills. Previous studies have confirmed that RME contributes positively to students' conceptual understanding, mathematical reasoning, problem-solving abilities, and critical thinking development (Koerunnisa et al., 2025).

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In addition to RME, the GASING Method (*Gampang, Asyik, dan Menyenangkan*- Easy, Fun, and Enjoyable) has emerged as an innovative approach to improving elementary mathematics learning. Developed by Yohanes Surya, GASING is designed to simplify mathematical concepts through systematic, enjoyable, and concept-oriented learning processes. The method emphasizes gradual progression from concrete experiences to abstract mathematical representations, enabling students to build conceptual understanding before applying formal mathematical symbols and procedures (Lahabu et al., 2025). The GASING approach is theoretically aligned with constructivist learning theory, which views students as active constructors of knowledge through interaction and meaningful experiences. Through structured learning stages, students are encouraged to explore concepts, recognize relationships, and develop mathematical reasoning skills (Putra & Jenuri, 2025).

Empirical studies have demonstrated that GASING contributes positively to mathematics learning outcomes, including numeracy achievement, learning motivation, self-confidence, and problem-solving abilities. Hayati et al. (2024) reported that GASING-based instruction significantly improved elementary students' mathematical performance by providing an engaging learning environment that supports active participation and conceptual understanding. However, previous GASING studies have mainly focused on mathematics achievement, numeracy skills, and motivation, while RME studies have emphasized mathematical literacy, conceptual understanding, and critical thinking development (Kurniawan & Latifatunnisa, 2024). Thus, although both approaches demonstrate strong potential individually, limited research has examined their integration within a unified instructional framework to enhance students' mathematical critical thinking skills.

The integration of GASING and RME theoretically offers a complementary instructional framework for developing elementary students' critical thinking. GASING provides a structured learning pathway that strengthens conceptual mastery through concrete-to-abstract progression, while RME contributes meaningful contextual situations that encourage students to apply mathematical ideas in real-life contexts. The combination of these approaches may create learning experiences that promote exploration, reasoning, reflection, and problem-solving simultaneously. Nevertheless, empirical evidence regarding the effectiveness of RME-integrated GASING in improving elementary students' mathematical critical thinking skills remains limited. Therefore, further investigation is needed to determine whether this integrated approach can effectively address the challenges of mathematics learning in elementary schools.

Based on this research gap, this study aims to investigate the effect of implementing the GASING Method integrated with RME on elementary school students' mathematical critical thinking skills. Specifically, this study examines whether the integration of GASING and RME can significantly improve students' critical thinking abilities in mathematics compared with conventional learning practices. The findings are expected to contribute empirical evidence for developing innovative mathematics instruction and provide practical implications for teachers and educational practitioners in designing learning experiences that are more contextual, meaningful, and effective in fostering students' higher-order thinking skills.

2. Method

This study employed a quantitative approach using a quasi-experimental method with a pretest–posttest nonequivalent control group design. This design was selected because the researcher was unable to randomly assign participants to experimental and control groups, while still seeking to examine the effect of the instructional intervention on students' critical thinking skills. Prior to the implementation of the treatment, both groups were administered a pretest to determine their initial level of mathematical critical thinking skills. After the intervention, a posttest was administered to measure changes in students' critical thinking performance.

The research design can be illustrated as follows:

Experimental Group: $O_1 - X_1 - O_2$
Control Group: $O_1 - X_2 - O_2$
Where:
O_1 = Pretest
O_2 = Posttest
X_1 = Instruction using the GASING Method integrated with RME
X_2 = Instruction using the GASING Method integrated with Contextual Teaching and Learning (CTL)

The population of this study consisted of elementary school students from Cluster 4 of Buton Regency, Indonesia. The sample comprised fourth-grade students from four different elementary schools within the cluster. A purposive sampling technique was employed to select schools that possessed relatively similar academic characteristics and learning conditions. The total number of participants was 96 students, divided equally into an experimental group and a control group, with 48 students in each group.

The intervention was conducted over four weeks consisting of eight instructional meetings, with each meeting lasting approximately 90 minutes. The mathematics materials taught during the intervention focused

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on elementary-level mathematical critical thinking competencies, including number operations, fractions, measurement, mathematical patterns, and contextual problem-solving. These topics were selected because they require students to analyze situations, develop solution strategies, evaluate mathematical procedures, and justify their reasoning. Before the intervention, both groups completed a pretest to measure their initial mathematical critical thinking skills. Following the intervention period, a posttest was administered to evaluate changes in students' critical thinking abilities after receiving different instructional treatments.

The experimental group received instruction through the GASING Method integrated with RME. The learning process was designed based on the principles of progressive mathematization, beginning with realistic problems related to students' daily experiences and gradually moving toward formal mathematical concepts. Each lesson consisted of several stages: (1) presenting contextual mathematical problems, (2) encouraging students to explore and identify mathematical ideas from real situations, (3) facilitating group discussions to compare various solution strategies, (4) guiding students to transform informal strategies into formal mathematical representations, and (5) reflecting on the mathematical concepts and reasoning processes developed during learning. Through these activities, students were encouraged to construct knowledge actively, develop mathematical reasoning, and strengthen critical thinking skills.

The control group received instruction through the GASING Method integrated with the CTL approach. Similar to the experimental group, learning activities were conducted through concrete experiences and contextual situations; however, the instructional process emphasized connecting mathematical concepts with students' existing knowledge and everyday experiences rather than the progressive mathematization characteristics of RME. The learning procedure included: (1) relating mathematical concepts to familiar real-life contexts, (2) explaining and demonstrating mathematical procedures using GASING strategies, (3) practicing mathematical skills through contextual exercises, (4) discussing students' solutions with teacher guidance, and (5) applying learned concepts to similar problems. This approach allowed students to develop mathematical understanding through meaningful connections between learning materials and their daily experiences.

The intervention was implemented consistently for both groups, with the same instructional duration, learning materials, and learning objectives. The main difference between the two groups was the instructional framework used to organize students' mathematical learning experiences. The experimental group emphasized realistic problem situations, student reinvention of mathematical ideas, and progressive mathematization through RME, whereas the control group emphasized contextual connections and application of mathematical concepts through CTL. This design enabled the study to examine the effect of integrating GASING with RME on students' mathematical critical thinking skills compared with GASING integrated with CTL.

The primary instrument used for data collection was a mathematical critical thinking skills test administered as both a pretest and a posttest. The test was developed based on critical thinking indicators adapted from mathematics education literature, including the abilities to identify mathematical problems, analyze information, evaluate arguments, formulate solution strategies, and draw logical conclusions. Prior to its administration, the instrument was subjected to expert validation to ensure content validity and appropriateness for elementary school students. Instrument reliability was subsequently examined using Cronbach's Alpha coefficient.

Data analysis was conducted using IBM SPSS software. Descriptive statistics, including mean scores, standard deviations, minimum scores, and maximum scores, were used to describe students' critical thinking performance before and after the intervention. Inferential statistical analyses were then employed to examine the effectiveness of the treatment. Prior to hypothesis testing, assumptions of normality and homogeneity were evaluated using the Shapiro–Wilk test and Levene's test, respectively. If the data met the assumptions of normality and homogeneity, an independent-samples t-test and paired-samples t-test were performed. Otherwise, appropriate non-parametric alternatives were employed. The level of statistical significance was set at $\alpha = 0.05$.

Through this procedure, the study sought to determine whether the implementation of the GASING Method integrated with RME had a significant effect on improving elementary school students' mathematical critical thinking skills compared with the GASING Method integrated with CTL.

3. Results and Discussion

Based on the Descriptive Statistics output generated using IBM SPSS, the data were analyzed systematically at a significance level of $\alpha = 0.05$. The first stage of the analysis involved descriptive statistics, which aimed to provide an overview of the characteristics of the research data through the presentation of mean scores, minimum and maximum scores, standard deviations, and the distribution of pretest and posttest scores for each research group. Descriptive statistical analysis plays an essential role in quantitative research because it enables researchers to obtain a general understanding of the data before conducting more advanced statistical procedures. Through descriptive statistics, researchers can identify measures of central tendency, examine the

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variability of scores, and observe changes occurring between the initial and final measurements. Consequently, the results of descriptive statistics serve as a foundation for understanding data patterns and determining appropriate subsequent analyses (Mishra et al., 2021; Mweshi & Sakyi, 2024).

Table 1 presents the descriptive statistics of students' mathematical critical thinking skills in both the experimental and control groups before and after the instructional intervention. The results indicate that both groups experienced improvements in their mean scores from pretest to posttest. In the experimental group, the mean score increased from 26.02 on the pretest to 47.40 on the posttest, representing an improvement of 21.38 points. Similarly, the control group showed an increase in mean score from 26.52 to 48.71, reflecting a gain of 22.19 points. These findings suggest that the instructional interventions implemented in both groups contributed positively to the development of students' mathematical critical thinking skills.

Table 1. Descriptive Statistics of Pretest and Posttest Scores for the Experimental and Control Groups

Group	Test	N	Minimum	Maximum	Mean	Standard Deviation
Experimental	Pretest	48	0	47	26.02	12.36
Experimental	Posttest	48	23	80	47.40	11.84
Control	Pretest	48	0	53	26.52	13.65
Control	Posttest	48	10	80	48.71	18.20

An important finding can also be observed in the changes in score variability. In the experimental group, the standard deviation decreased from 12.36 during the pretest to 11.84 during the posttest. This reduction indicates that students' learning outcomes became more homogeneous after receiving instruction through the GASING Method integrated with RME. In other words, the improvement in critical thinking skills was distributed more evenly among students. By contrast, the control group demonstrated an increase in standard deviation from 13.65 to 18.20, suggesting greater variability in students' posttest performance. This finding indicates that although students in the control group improved on average, the magnitude of improvement varied considerably among individuals.

The minimum and maximum scores further illustrate the changes in students' achievement. In the experimental group, the minimum score increased substantially from 0 on the pretest to 23 on the posttest, while the maximum score rose from 47 to 80. Similarly, the control group experienced an increase in the minimum score from 0 to 10 and in the maximum score from 53 to 80. These improvements indicate that students in both groups benefited from the learning interventions. However, the higher minimum posttest score and lower standard deviation observed in the experimental group suggest that the RME-based GASING Method may have been more effective in supporting lower-achieving students and reducing disparities in learning outcomes.

From an educational perspective, the findings imply that integrating the GASING Method with Realistic Mathematics Education provides a learning environment that promotes not only academic improvement but also greater equity in learning achievement. The contextual and student-centered characteristics of RME encourage learners to actively construct mathematical understanding through meaningful real-life situations, thereby facilitating broader participation and engagement during the learning process. As a result, students with different levels of prior knowledge may have more opportunities to develop their critical thinking skills effectively. Furthermore, descriptive statistics serve as the initial step in the data analysis process by providing information about the general characteristics of the research data before inferential testing is conducted. The presentation of mean scores, standard deviations, minimum scores, and maximum scores enables researchers to gain a comprehensive understanding of the data, including the degree of variability and the patterns of change occurring within each group. This information also assists in evaluating the suitability of the data for further statistical analyses. Consequently, the findings derived from descriptive statistics provide a foundation for conducting normality tests, homogeneity tests, and hypothesis testing to determine whether the observed differences or improvements are statistically significant. Therefore, descriptive statistical results not only offer a preliminary overview of the data but also serve as an important basis for data interpretation and the formulation of research conclusions (Hair et al., 2022; Mishra et al., 2021).

Overall, the descriptive statistics provide preliminary evidence that both instructional approaches contributed to improvements in students' mathematical critical thinking skills. Nevertheless, the experimental group demonstrated a more balanced distribution of achievement, indicating the potential advantage of integrating the GASING Method with Realistic Mathematics Education. Further inferential statistical analyses were therefore conducted to determine whether the observed differences between groups were statistically significant.

To provide a more comprehensive understanding of the development of students' critical thinking skills following the instructional intervention, a comparison of pretest and posttest results was conducted for both the experimental and control groups. This comparison includes changes in mean scores, minimum scores,

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maximum scores, and standard deviations for each group. The analysis aims to identify the extent of improvement in students' critical thinking skills as well as the distribution of learning outcomes after the intervention. The comparison of pretest and posttest scores is presented in Table 2.

Table 2. Comparison of Changes in Pretest and Posttest Scores

Group	Δ Mean	Δ Minimum	Δ Maximum	Change in SD
Experimental	+21.38	+23	+33	-0.52
Control	+22.19	+10	+27	+4.55

Note:
Δ Mean = Difference between the posttest and pretest mean scores.
Δ Minimum = Difference between the posttest and pretest minimum scores.
Δ Maximum = Difference between the posttest and pretest maximum scores.
Change in SD = Difference between the posttest and pretest standard deviations.

Based on Table 2, both groups demonstrated a substantial increase in their mean scores following the implementation of the instructional interventions. This improvement is reflected in the positive Δ Mean values observed in both the experimental and control groups, indicating that students' learning outcomes improved from the initial measurement (pretest) to the final measurement (posttest). These findings suggest that the instructional approaches implemented in both groups contributed positively to students' development compared to their performance before the intervention. In general, the increase in mean scores across both groups indicates that students gained meaningful learning experiences that helped them better understand the instructional content and improve the skills assessed in this study. These findings are consistent with previous research showing that systematically and well-structured instructional processes can positively influence students' academic development (Mutmainnah et al., 2025; Charytanowicz et al., 2024).

The experimental group achieved an average improvement of 21.38 points, while the control group showed an average improvement of 22.19 points. In addition, increases in both minimum and maximum scores were observed in the two groups, indicating that students with varying ability levels both low-achieving and high-achieving learners experienced progress after participating in the learning activities. In the experimental group, the minimum score increased by 23 points and the maximum score increased by 33 points. Meanwhile, in the control group, the minimum score increased by 10 points and the maximum score increased by 27 points. These results demonstrate that students' learning achievements in both groups improved positively following the instructional interventions. The increase in minimum scores suggests that students who initially demonstrated relatively low performance were able to achieve meaningful progress after instruction. Conversely, the increase in maximum scores indicates that higher-achieving students also benefited from the learning process. According to Rahmawati (2024), improvements in mean scores and changes in score ranges serve as preliminary indicators of student learning development following instructional interventions. Therefore, the score changes observed in both groups may be regarded as initial evidence of improved student performance after receiving the instructional treatments.

Although both groups demonstrated improvements in learning outcomes, a notable difference emerged regarding changes in standard deviation. The experimental group experienced a decrease in standard deviation of 0.52 points. This reduction indicates that the distribution of students' scores became less dispersed after the intervention than before it. In other words, learning outcomes within the experimental group became more homogeneous and evenly distributed. This finding suggests that the improvement in performance was not limited to a small number of students but was experienced by most learners in the group. A lower standard deviation indicates that students' scores are clustered more closely around the group mean, reflecting a higher degree of consistency in learning achievement. In educational settings, such a condition may indicate that the instructional treatment effectively supported students with different ability levels in progressing together without creating substantial achievement gaps. In descriptive statistical analysis, a decrease in standard deviation following an intervention is often interpreted as evidence of improved consistency and equity in students' learning outcomes within a group (Félix et al., 2024; Nugraha & Rudhito, 2025).

In contrast, the control group exhibited an increase in standard deviation of 4.55 points. This increase suggests that the variability of students' scores became greater after the instructional intervention compared to the pretest condition. Such a result indicates that differences in learning achievement among students widened over time, with some students showing substantial improvement while others demonstrated relatively smaller gains. Consequently, the distribution of learning outcomes in the control group was less equitable than that observed in the experimental group. The increase in standard deviation also implies that the instructional approach affected students differently depending on their individual characteristics and prior abilities. As a result, score distributions became more dispersed and group homogeneity decreased. This finding is consistent with the argument of Huda et al. (2024), who stated that higher standard deviation values reflect greater variability in students' abilities within a group. Therefore, the increase in standard deviation observed in the control group may be interpreted as an indication that the instructional intervention did not affect all students equally.

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Overall, the findings presented in Table 2 provide preliminary evidence that the instructional treatment implemented in the experimental group not only contributed to improved student achievement but also promoted a more equitable distribution of learning outcomes. The decrease in standard deviation suggests that the instructional approach helped students with diverse ability levels develop in a more balanced and consistent manner. In addition to improving overall group performance, the intervention appears to have reduced achievement disparities among students, thereby creating a more inclusive and effective learning environment. Conversely, the increase in standard deviation observed in the control group indicates that learning outcomes became more varied among students, suggesting that the benefits of instruction were not distributed equally across the group. Therefore, the descriptive data presented in Table 2 provide an initial indication that the treatment applied in the experimental group was more effective in supporting both the improvement and equalization of students' learning achievements. Nevertheless, these findings remain descriptive in nature; therefore, further inferential statistical analyses are required to determine whether the differences observed between the two groups are statistically significant (Mubarakah & Abdullah, 2025; Voke et al., 2025).

The findings of this study indicate that both the experimental group receiving the PMR-based GASING Method and the control group receiving the CTL-based GASING Method experienced improvements in students' mathematical critical thinking skills. The improvement observed in both groups suggests that the GASING Method itself contributed positively to students' mathematical learning development. GASING provides a structured learning sequence that moves from concrete experiences toward abstract mathematical understanding, allowing students to develop conceptual mastery through gradual and meaningful activities. The emphasis on visualization, mental calculation strategies, and systematic problem-solving processes may have supported students in analyzing mathematical situations and constructing logical reasoning. Furthermore, both instructional approaches provided students with active learning experiences, opportunities for discussion, and contextual mathematical activities, which are important factors in developing critical thinking skills.

The higher improvement observed in the experimental group suggests that integrating GASING with PMR provided additional benefits in strengthening students' mathematical critical thinking. PMR emphasizes the use of realistic problems as starting points for learning, allowing students to construct mathematical ideas through exploration, argumentation, and reflection. Through the process of progressive mathematization, students are encouraged to move from informal strategies based on real contexts toward more formal mathematical reasoning. This learning process supports critical thinking components, including identifying problems, evaluating solution strategies, making connections between representations, and justifying mathematical conclusions. Therefore, the combination of GASING's systematic conceptual development and PMR's contextual problem-solving orientation may create a more cognitively engaging learning environment.

The experimental group also demonstrated more homogeneous learning outcomes compared with the control group, as indicated by the smaller variation in students' posttest scores. This finding may be explained by the structured characteristics of PMR-based GASING instruction, which provides a consistent learning pathway for students with different initial abilities. The use of contextual problems, guided exploration, group discussion, and progressive mathematical representations may enable students to gradually develop similar levels of understanding. In addition, PMR allows students to share and compare multiple solution strategies, reducing disparities among students by creating opportunities for peer learning and mathematical communication. As a result, students' learning gains in the experimental group tended to be more evenly distributed.

However, the descriptive results also showed that the control group obtained a slightly higher mean score compared with the experimental group. This finding should be interpreted carefully because a higher average score does not necessarily indicate that one instructional approach is more effective in developing critical thinking skills. Several factors may have contributed to this result, including differences in students' initial abilities, classroom dynamics, students' familiarity with contextual learning activities, or variations in students' responses to the learning approach. The CTL-based GASING approach may have provided students with more direct connections between mathematical concepts and familiar daily experiences, which could have supported higher immediate achievement in some students. Meanwhile, the PMR-based GASING approach requires students to engage in deeper exploration, construct mathematical models, and justify their reasoning, which may require a longer adaptation period before producing optimal outcomes.

Therefore, the effectiveness of the PMR-based GASING Method should not be evaluated solely based on mean score differences but also through improvements in critical thinking development and the distribution of learning outcomes. The findings suggest that PMR-based GASING has strong potential to promote deeper mathematical reasoning and more consistent student achievement. Future studies with longer intervention periods, larger samples, and more controlled experimental designs are recommended to further examine the long-term impact of PMR-based GASING on students' mathematical critical thinking skills.

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3.1. Implications for Educational Research

The findings of this study provide several important implications for educational research, particularly in the field of mathematics education and the development of higher-order thinking skills among elementary school students. The results indicate that the integration of the GASING Method with Realistic Mathematics Education (RME) has the potential not only to improve students' mathematical critical thinking skills but also to promote a more equitable distribution of learning outcomes. This finding reinforces the view that effective mathematics instruction should combine systematic conceptual learning with meaningful real-life contexts that encourage active student participation. Consequently, the study contributes to the growing body of evidence supporting student-centered and context-based learning approaches as effective strategies for fostering critical thinking in mathematics education.

Furthermore, this study expands the existing literature by providing empirical evidence on the integration of the GASING Method and RME, two approaches that have frequently been examined separately in previous studies. The findings suggest that combining the structured and progressive learning stages of GASING with the contextual and problem-oriented characteristics of RME can create a learning environment that supports both conceptual understanding and critical thinking development. Therefore, future educational research should explore the effectiveness of this integrated approach in different educational settings, grade levels, and mathematical topics to determine its broader applicability and effectiveness.

In addition, the findings highlight the importance of investigating other factors that may influence the effectiveness of innovative instructional approaches. Future studies may examine the role of variables such as learning motivation, self-efficacy, mathematical disposition, student engagement, collaborative learning, and problem-solving skills in mediating the relationship between instructional methods and critical thinking outcomes. Such investigations would contribute to a more comprehensive understanding of how innovative learning models affect students' cognitive and affective development. Ultimately, this study provides a foundation for further research aimed at developing evidence-based instructional models that can improve the quality of mathematics education and better prepare students for the demands of 21st-century learning.

3.2. Limitations

Despite its contributions, this study has several limitations that should be considered when interpreting the findings. First, the study employed a quasi-experimental design with nonequivalent control groups, which limits the extent to which causal inferences can be made. Although the experimental and control groups were selected to have relatively similar characteristics, the absence of random assignment means that pre-existing differences between groups may have influenced the results.

Second, the study was conducted with a relatively limited sample consisting of 96 fourth-grade students from four elementary schools within a single educational cluster in Buton Regency. As a result, the generalizability of the findings to other educational contexts, regions, and student populations may be limited. Future studies involving larger and more diverse samples are needed to validate and extend the findings of this research. Another limitation concerns the scope of the outcome variable examined in this study. The research focused solely on students' mathematical critical thinking skills and did not investigate other potentially important learning outcomes such as mathematical reasoning, problem-solving ability, creativity, learning motivation, self-confidence, or academic achievement. Including these variables in future studies would provide a more comprehensive understanding of the impact of the GASING Method integrated with RME.

Finally, the duration of the intervention was limited to the period of the study, making it difficult to determine whether the observed improvements in critical thinking skills would be sustained over a longer period. Longitudinal research is therefore recommended to examine the long-term effects of the instructional approach and to determine whether the improvements achieved can be maintained and transferred to other mathematical learning contexts. Despite these limitations, the findings offer valuable preliminary evidence regarding the potential effectiveness of integrating the GASING Method with Realistic Mathematics Education in enhancing elementary school students' mathematical critical thinking skills.

4. Conclusion

Overall, the descriptive statistical results indicate that both instructional treatments implemented in this study were effective in improving students' abilities. However, the instructional approach applied in the experimental group demonstrated a greater tendency to support the equitable development of students' skills across the entire group. In addition to contributing to improved learning outcomes, the treatment administered in the experimental group also showed a stronger capacity to produce a more homogeneous distribution of achievement compared to the control group. Therefore, the descriptive data provide preliminary evidence that the implementation of the GASING Method integrated with Realistic Mathematics Education (RME) has greater potential to enhance and equalize elementary school students' mathematical critical thinking skills than the GASING Method integrated with Contextual Teaching and Learning (CTL). Nevertheless, the conclusions drawn from the descriptive analysis remain preliminary and cannot yet be used to confirm the existence of statistically

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significant differences between the two groups. Consequently, further inferential statistical analyses, including tests of normality, homogeneity, and hypothesis testing, are required to obtain stronger empirical evidence regarding the significance of the observed differences. The results of these inferential analyses will serve as the primary basis for determining whether the implementation of the GASING Method integrated with Realistic Mathematics Education is indeed more effective in improving elementary school students' mathematical critical thinking skills than the GASING Method integrated with Contextual Teaching and Learning.

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The authors declared no potential conflicts of interest with respect to the research, authorship, and/ or publication of this article.

Data Availability

The datasets generated during and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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