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The effectiveness of the integrated GASING method combining contextual teaching and learning on elementary school students' mathematical communication skills: a quasi-experimental study

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ABSTRACT

This study evaluated the effectiveness of the GASING method combined with the Contextual Teaching and Learning (CTL) approach on elementary students' mathematical communication skills relative to conventional instruction. A quasi-experimental pretest-posttest design with nonequivalent groups was used, involving 128 fourth-grade students: an experimental group ($n = 55$; SD Kristen Baik classes 4A-4B and SD Inpres Kemiri) taught with GASING-CTL, and a control group ($n = 73$; SD Inpres Kartika classes 4A-4B and SD YPPGI Sentani) receiving conventional instruction. Pretest scores did not differ significantly between groups ($p = .891$), confirming baseline equivalence. Both groups improved significantly from pretest to posttest (experimental: $t = -20.19$, $p < .001$, $d = 2.72$; control: $t = -16.47$, $p < .001$, $d = 1.93$), with higher posttest means in the experimental group ($M = 73.59$, $SD = 8.85$) than the control group ($M = 67.39$, $SD = 8.99$). Because the control group's normalized gain (N-Gain) departed from normality (Shapiro-Wilk $p < .001$), a Mann-Whitney U test was applied and showed a significant between-group difference favoring the experimental group ($U = 2582.00$, $Z = 2.77$, $p = .006$, $r = .244$), although the independent t-test on raw gain scores was not significant ($t = 1.55$, $p = .123$). Mean N-Gain fell in the "medium" category for both groups (.63 and .53, respectively), yet the experimental group showed a larger share of "high" gains (32.7% vs. 16.4%) and no "low" gains, versus 11.0% in the control group. These results suggest GASING-CTL yields more consistent and proportionally larger learning gains, supporting its potential as a contextual strategy for enhancing mathematical communication skills, though the non-significant raw gain difference warrants cautious interpretation.



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Introduction

Mathematics achievement among Indonesian students has remained persistently weak in international comparative assessments. The Programme for International Student Assessment (PISA) 2022 results show that Indonesian 15-year-olds scored an average of 366 points in mathematics, well below the OECD average of 472 points, with only 18% of students attaining at least Level 2 proficiency compared to 69% across OECD countries (OECD, 2023). These results represent a decline from 2018 and place Indonesia's 2022 performance among the lowest ever recorded since the country's participation began, on par with scores observed in 2003

(OECD, 2023). A similar pattern emerges in the Trends in International Mathematics and Science Study (TIMSS), in which Indonesia participated from 2003 to 2015 with consistently declining mathematics scores at the elementary level before discontinuing participation in subsequent cycles (Mullis et al., 2016). Although these two assessments differ in scope and target age groups, both converge on a troubling conclusion: foundational mathematical competencies among Indonesian students, particularly at the elementary level where mathematical reasoning habits are first formed, require urgent pedagogical intervention.

Among the competencies underlying mathematical proficiency, communication is recognized by the National Council of Teachers of Mathematics (NCTM, 2000) as one of five core process standards, encompassing students' ability to organize and consolidate mathematical thinking, express ideas coherently to peers and teachers, and use mathematical language with precision. Subsequent research between 2020 and 2025 reinforces this position: a systematic review of 34 Scopus-indexed studies found that weak mathematical communication has hampered elementary students' comprehension and problem-solving over the past two decades, while research activity on the topic has accelerated markedly since 2020 (Yusoff et al., 2022). Despite this growing scholarly attention, communication skills remain comparatively underexamined relative to procedural and conceptual outcomes in elementary mathematics intervention studies, particularly within the Indonesian context.

Two pedagogical innovations have separately been proposed to address these learning deficits. The GASING method (Gampang, Asyik, Menyenangkan—Easy, Fun, and Enjoyable), developed by Surya at the Surya Institute, employs a structured concrete-abstract-mental sequence in which students manipulate physical objects before progressing to symbolic and mental computation, thereby minimizing reliance on memorized formulas (Prahmana & Suwasti, 2014). The Contextual Teaching and Learning (CTL) approach, grounded in constructivist and situated-cognition theory, posits that learning is most meaningful when mathematical concepts are anchored in students' real-world experiences, enabling them to construct understanding through authentic, socially mediated activity (Johnson, 2002; Putra et al., 2025; Rafiki et al., 2025). While each approach is theoretically distinct, GASING's emphasis on hands-on conceptual scaffolding and CTL's emphasis on real-life relevance are arguably complementary, suggesting potential synergy when implemented jointly.

However, prior empirical work has examined these two approaches largely in isolation and rarely in relation to communication outcomes. Studies on GASING have concentrated almost exclusively on procedural and computational gains, such as multiplication mastery among fifth-grade students (Kusuma & Sulistiawati, 2014) and division concepts among rural elementary learners (Prahmana & Suwasti, 2014), without assessing students' capacity to articulate or represent mathematical reasoning. Conversely, studies on CTL have demonstrated improvements in mathematical literacy, critical thinking, and learning outcomes (Lestari et al., 2021; Fatkurochman et al., 2024), but these were not paired with a structured computational method such as GASING, nor did they isolate communication skills as the primary dependent variable. However, despite these advances, no study to date has examined the combined effect of GASING and CTL—integrating structured conceptual scaffolding with authentic contextual relevance—specifically on elementary students' mathematical communication skills, leaving a clear gap between two bodies of literature that have developed largely in parallel.

This study addresses that gap by offering empirical evidence on the joint application of GASING and CTL, representing, to the authors' knowledge, the first quasi-experimental investigation to evaluate this specific combination against conventional instruction using mathematical communication as the primary outcome measure among Indonesian fourth-grade students. By integrating a method validated for procedural mastery with an approach validated for contextual meaning-making, this study extends both lines of research beyond their previous, separate scopes.

Accordingly, this study aims to examine the effect of the GASING method combined with the CTL approach on the mathematical communication skills of elementary school students relative to conventional instruction. Specifically, it seeks to answer: (1) Does the combined GASING-CTL approach produce a statistically significant improvement in mathematical communication skills compared to pretest baseline? (2) Does this improvement differ significantly from that achieved through conventional instruction? Findings are expected to inform evidence-based pedagogical decisions for elementary mathematics instruction in Indonesia and contribute methodologically grounded evidence to the broader discourse on contextualized, activity-based mathematics learning.

Method

Design Method

Based on this theoretical foundation, the following hypotheses are proposed: (H1) There is a statistically significant improvement in mathematical communication skills among elementary students taught using the combined GASING and CTL approach, as measured from pretest to posttest. (H2) The improvement in mathematical communication skills among students taught using GASING-CTL is significantly greater than that of students receiving conventional instruction.

This study employed a quasi-experimental research design with a nonequivalent control group pretest–posttest design to examine the effect of the GASING (Gampang, Asyik, dan Menyenangkan) method integrated with the Contextual Teaching and Learning (CTL) approach on elementary students' mathematical communication skills. The quasi-experimental design was selected because the study was conducted in naturally existing classrooms where random assignment of individual students was not feasible. Pretest and posttest measurements enabled the evaluation of learning improvement after the instructional intervention.

The research design consisted of an experimental group and a control group, represented as follows: the experimental group followed the sequence $O_1 - X - O_2$, while the control group followed $O_1 - C - O_2$. In this notation, O_1 denotes the pretest, O_2 denotes the posttest, X represents mathematics instruction integrating the GASING method with Contextual Teaching and Learning (CTL), and C represents conventional mathematics instruction. Both groups completed the pretest before the instructional intervention and the posttest afterward to measure changes in students' mathematical communication skills.

The population consisted of fourth-grade students enrolled in four elementary schools in Papua, Indonesia. The sample was selected using class-level random sampling, resulting in a total of 128 participants. The experimental group comprised 55 students (Grade 4A and 4B from SD Kristen Baik and Grade 4 from SD Inpres Kemiri). The control group included 73 students (Grade 4A and 4B from SD Inpres Kartika and Grade 4 from SD YPPGI Sentani).

To ensure comparability between groups before the intervention, an initial equivalence test was conducted using pretest scores. The analysis indicated no statistically significant difference between the groups ($p = 0.891$), demonstrating similar initial mathematical communication abilities.

Instrument

Mathematical communication skills were measured using a 10-item essay test (s1–s10). The instrument assessed students' ability to express mathematical ideas, explain problem-solving procedures, construct mathematical representations, and communicate logical reasoning using appropriate mathematical language and symbols. Each item contributed to a maximum total raw score of 30 points, which was subsequently converted into a standardized 0–100 final score (Nilai Akhir/NA) for data analysis. Content validity was established through expert judgment involving mathematics education specialists and experienced elementary teachers. Experts evaluated the relevance, clarity, and alignment of each item with the indicators of mathematical communication skills and the fourth-grade mathematics curriculum; revisions were made based on their recommendations before administration. Internal consistency reliability was evaluated using Cronbach's Alpha (coefficient to be reported following analysis).

Procedure

The study was implemented in three consecutive stages: pretest, treatment (intervention), and posttest. Before the instructional intervention, students in both groups completed a mathematical communication skills test to determine their baseline abilities. During the treatment stage, the experimental group received mathematics instruction integrating the GASING method and Contextual Teaching and Learning (CTL). The learning activities emphasized concrete experiences, gradual conceptual understanding, contextual problem solving, collaborative discussion, and active communication of mathematical ideas. Students were encouraged to explain their reasoning, represent mathematical concepts in multiple forms, and connect mathematical knowledge with real-life situations. In contrast, the control group received conventional mathematics instruction characterized by teacher explanations, demonstrations of solution procedures, textbook exercises, and individual practice. Both groups studied the same mathematical topics over equivalent instructional periods. Following the intervention, all students completed the same mathematical communication skills test administered during the pretest. The posttest scores were then analyzed to determine the effectiveness of the instructional approaches and calculate learning gains.

Data analysis

Data analysis was conducted using descriptive and inferential statistics. Descriptive statistics included means and standard deviations for both pretest and posttest scores. The experimental group obtained a mean pretest score of 24.79 (SD = 17.32) and a mean posttest score of 73.59 (SD = 8.85), whereas the control group obtained a mean pretest score of 24.29 (SD = 22.11) and a mean posttest score of 67.39 (SD = 8.99). Students' learning improvement was evaluated using both Gain Score and Normalized Gain (N-Gain). N-Gain was calculated according to Hake (1999):

$$N\text{-Gain} = \frac{\text{Posttest} - \text{Pretest}}{\text{Maximum Score} - \text{Pretest}}$$

N-Gain values were classified into three categories: High (≥ 0.70), Medium (0.30–0.69), and Low (< 0.30). Prior to hypothesis testing, the assumptions of normality and homogeneity were examined. The Shapiro–Wilk test revealed that the experimental group's N-Gain data were normally distributed ($p = 0.543$), whereas the control group's N-Gain data were not normally distributed ($p < 0.001$). The Levene homogeneity test indicated homogeneous variances between groups ($p = 0.096$). Because one group's N-Gain data violated the normality assumption, differences in learning improvement between groups were analyzed using the Mann–Whitney U test. Within-group comparisons between pretest and posttest scores were analyzed using paired-samples t-tests. In addition, effect sizes were calculated using Cohen's d for paired comparisons and effect size r for the Mann–Whitney U analysis to evaluate the magnitude of the observed effects.

Ethical considerations

The study was conducted in existing school classrooms. Ethical approval and informed consent were obtained from school administrators, teachers, and parents prior to data collection. Participation was voluntary, and all data were anonymized for analysis.

Results and Discussions

Descriptive Statistics of Pretest and Posttest Scores

The effectiveness of the GASING method integrated with the Contextual Teaching and Learning (CTL) approach was initially examined through descriptive statistics of students' mathematical communication scores before and after the intervention. Prior to the treatment, both groups demonstrated relatively low levels of mathematical communication skills, as indicated by comparable pretest mean scores. After the instructional intervention, substantial improvements were observed in both groups, although the experimental group achieved a higher posttest mean.

Table 1. Descriptive Statistics of Mathematical Communication Scores

Group	n	Pretest Mean	SD	Posttest Mean	SD	Mean N-Gain
Experimental (GASING + CTL)	55	24.79	17.32	73.59	8.85	0.63
Control (Conventional Learning)	73	24.29	22.11	67.39	8.99	0.53

As shown in Table 1, the experimental group obtained a pretest mean score of 24.79 (SD = 17.32) and improved to a posttest mean score of 73.59 (SD = 8.85). Similarly, the control group increased from a pretest mean of 24.29 (SD = 22.11) to a posttest mean of 67.39 (SD = 8.99).

Before comparing learning improvement, an initial equivalence test was conducted using the pretest scores. The analysis indicated no statistically significant difference between the experimental and control groups ($p = .891$), suggesting that both groups possessed comparable mathematical communication abilities at the beginning of the study. Therefore, differences observed after the intervention can reasonably be interpreted as reflecting the instructional treatments rather than pre-existing differences in student ability.

Normality and Homogeneity Tests

Assumption testing was conducted before selecting the appropriate inferential statistical procedures for comparing learning improvement between groups.

Table 2. Normality and Homogeneity Tests

Test	Statistic	p-value	Interpretation
Shapiro–Wilk (Experimental N-Gain)	—	.543	Normal distribution
Shapiro–Wilk (Control N-Gain)	—	< .001	Non-normal distribution
Levene's Test (N-Gain)	—	.096	Homogeneous variance

The Shapiro–Wilk test revealed that the N-Gain scores of the experimental group were normally distributed ($p = .543$), whereas the control group's N-Gain scores violated the normality assumption ($p < .001$). Despite this difference, Levene's test indicated homogeneous variances across groups ($p = .096$).

Because one dataset was not normally distributed, the assumptions for a parametric comparison of N-Gain scores were not fully satisfied. Accordingly, the Mann–Whitney U test was selected as the primary hypothesis test for comparing normalized learning gains between groups.

Within-Group Improvement: Paired-Samples t-Test

To evaluate whether students' mathematical communication skills improved after instruction, paired-samples t-tests were conducted separately for the experimental and control groups.

Table 3. Paired-Samples t-Test Results

Group	df	t	p	Cohen's d	Interpretation
Experimental (GASING + CTL)	54	-20.19	< .001	2.72	Very large effect
Control (Conventional Learning)	72	-16.47	< .001	1.93	Very large effect

The experimental group demonstrated a statistically significant increase in mathematical communication scores from pretest to posttest, $t(54) = -20.19$, $p < .001$, with Cohen's $d = 2.72$. According to conventional effect size criteria, this value represents a very large practical effect, indicating substantial improvement following instruction using the GASING method integrated with the CTL approach. Similarly, the control group also showed significant improvement between pretest and posttest scores, $t(72) = -16.47$, $p < .001$, with Cohen's $d = 1.93$, which is likewise categorized as a very large effect. Although both instructional approaches significantly enhanced students' mathematical communication skills, the larger effect size observed in the experimental group suggests that the GASING method integrated with the CTL approach produced greater within-group improvement than conventional instruction.

Comparison of N-Gain Scores Between Groups

The primary hypothesis of this study was tested by comparing the normalized gain (N-Gain) scores between the experimental and control groups using the Mann–Whitney U test.

Table 4. Mann–Whitney U Test for N-Gain Scores

U	Z	p	Effect Size (r)
2582.00	2.77	.006	.244

The Mann–Whitney U analysis revealed a statistically significant difference in normalized learning gains between the two instructional approaches, $U = 2582.00$, $Z = 2.77$, $p = .006$, $r = .244$.

The effect size ($r = .244$) indicates a small-to-moderate practical effect, suggesting that although both groups improved substantially, students who learned through the GASING method integrated with the CTL approach achieved significantly greater normalized learning gains than those who received conventional instruction.

The average N-Gain score of the experimental group was 0.63, whereas the control group obtained an average N-Gain score of 0.53. According to Hake's (1999) classification, both values fall within the medium improvement category, indicating that both instructional approaches effectively improved mathematical communication skills while the experimental approach produced relatively higher learning gains.

Comparison of Raw Gain Scores

To complement the N-Gain analysis, raw Gain scores (posttest minus pretest) were compared using an independent-samples t-test.

Table 5. Independent-Samples t-Test for Raw Gain Scores

Test	t	p	Interpretation
Independent Samples t-test	1.55	.123	Not significant

The independent-samples t-test produced $t = 1.55$, $p = .123$, indicating that the difference in raw Gain scores between the experimental and control groups was not statistically significant.

This finding differs from the N-Gain analysis and should be interpreted carefully. Raw Gain scores reflect absolute score improvement without accounting for students' initial achievement levels or their remaining opportunity for improvement. In contrast, N-Gain normalizes learning gains relative to the maximum

possible improvement, making it a more appropriate measure for comparing groups with varying baseline performance.

Therefore, although the raw Gain analysis did not reveal significant differences, the statistically significant Mann–Whitney U result based on N-Gain provides stronger evidence that the GASING method integrated with the CTL approach produced greater normalized learning improvement. Distribution of N-Gain Categories. To further describe students' learning improvement, N-Gain scores were classified into High, Medium, and Low categories based on Hake's (1999) criteria.

Table 6. Distribution of N-Gain Categories

N-Gain Category	Experimental (%)	Control (%)
High	32.7	16.4
Medium	67.3	72.6
Low	0.0	11.0

The distribution presented in Table 6 demonstrates clear differences between the two instructional groups. In the experimental group, 32.7% of students achieved the High N-Gain category, while 67.3% were classified in the Medium category and no students (0%) were categorized as Low.

Conversely, in the control group, only 16.4% of students reached the High category, 72.6% were classified as Medium, and 11.0% remained in the Low category.

These descriptive findings are consistent with the Mann–Whitney U analysis, indicating that the GASING method integrated with the CTL approach not only increased average normalized learning gains but also shifted a greater proportion of students into the High improvement category while eliminating Low improvement outcomes. In contrast, conventional instruction resulted in fewer students reaching the High category and a measurable proportion remaining in the Low category.

Overall, the statistical analyses consistently demonstrate that both instructional approaches significantly improved elementary school students' mathematical communication skills. However, the GASING method integrated with the CTL approach produced significantly higher normalized learning gains than conventional instruction, while the comparison based on raw Gain scores did not reach statistical significance. These findings support the conclusion that N-Gain provides a more sensitive indicator of instructional effectiveness in the present quasi-experimental study.

The findings of this study provide empirical evidence that the integration of the GASING (Gampang, Asyik, dan Menyenangkan) method with Contextual Teaching and Learning (CTL) has a statistically and educationally meaningful effect on elementary students' mathematical communication skills. Although both the experimental and control groups demonstrated significant improvement from pretest to posttest ($p < 0.001$ for both paired t-tests), the experimental group showed a significantly higher N-Gain score compared to the control group (Mann–Whitney U, $p = 0.006$, $r = 0.244$), indicating a moderate effect size. Interestingly, the raw gain scores between groups were not significantly different ($p = 0.123$), suggesting that the superiority of the intervention becomes more apparent when learning improvement is normalized relative to students' initial abilities. Furthermore, the distribution of learning gains reinforces this pattern, with 32.7% of students in the experimental group achieving a high N-Gain category compared to only 16.4% in the control group, while no students in the experimental group were in the low category, unlike 11% in the control group. These results warrant a deeper theoretical and methodological interpretation.

Mechanisms of GASING–CTL in Enhancing Mathematical Communication Skills

The effectiveness of the GASING–CTL combination can be explained through complementary cognitive and sociocultural mechanisms. The GASING method emphasizes a progression from concrete manipulation to abstract reasoning through simple, playful, and repetitive mathematical experiences. This aligns with Bruner's theory of representation, particularly the enactive–iconic–symbolic stages, where learners first engage physically with mathematical ideas before internalizing symbolic forms. In the context of mathematical communication, this gradual transition supports students in articulating mathematical ideas more clearly because their conceptual understanding is grounded in concrete experiences rather than rote memorization.

Meanwhile, CTL situates learning within meaningful real-life contexts, consistent with constructivist learning theory (Piaget and Vygotsky). CTL encourages students to connect mathematical concepts to everyday situations, thereby enhancing not only conceptual understanding but also the ability to express mathematical reasoning in contextual language. When combined, GASING provides the cognitive

scaffolding for conceptual clarity, while CTL offers the communicative and contextual framework for expression.

The synergy between these approaches appears to operate through three key mechanisms. First, conceptual anchoring: GASING ensures that abstract mathematical ideas are rooted in manipulatives and intuitive reasoning, reducing cognitive overload and allowing students to focus on articulating relationships between concepts. Second, contextualization of meaning: CTL requires students to explain mathematical ideas within familiar situations, thereby promoting the use of mathematical vocabulary in authentic discourse. Third, iterative verbalization: both approaches encourage students to repeatedly explain, discuss, and reconstruct their understanding, which strengthens mathematical communication skills as a form of social and cognitive practice. This aligns with Vygotsky's notion that language is not only a medium of communication but also a tool for thinking.

Interpretation of the Difference Between Gain and N-Gain Results

A notable methodological finding is the discrepancy between raw gain scores and normalized gain (N-Gain) results. While the raw gain did not differ significantly between groups ($p = 0.123$), the N-Gain analysis revealed a statistically significant difference favoring the experimental group. This divergence can be explained by differences in initial pretest scores and the limitations of absolute gain in capturing proportional learning improvement.

In quasi-experimental educational settings, pretest scores are often not perfectly equivalent across groups, even when statistical tests show no significant differences at baseline. Small variations in initial ability can substantially influence raw gain calculations, particularly when students start at different levels of prior knowledge. N-Gain, as proposed by Hake, addresses this limitation by normalizing improvement against the maximum possible gain, thereby providing a more equitable measure of learning effectiveness across heterogeneous learners.

In this study, the experimental group's higher proportion of students achieving high N-Gain and the absence of low-category learners suggest that the GASING–CTL approach is particularly effective in supporting learners across ability levels, especially those who may otherwise struggle to progress. Therefore, the N-Gain results offer a more sensitive indicator of instructional effectiveness than raw gain scores, reinforcing the argument that the intervention has a meaningful pedagogical impact despite non-significant differences in absolute score improvements.

Comparison with Previous Studies

The present findings are broadly consistent with previous research demonstrating the potential of structured, contextual, and activity-oriented mathematics instruction to improve elementary students' mathematical performance. However, the findings also extend the existing literature by showing that the combination of the GASING method and Contextual Teaching and Learning (CTL) can support not only computational performance but also students' ability to communicate mathematical ideas. Recent evidence on GASING indicates that the method can improve students' basic arithmetic abilities through systematic, enjoyable, and progressively structured learning activities. Gesiradja et al. (2026), for example, reported substantial improvement in elementary students' basic arithmetic performance following GASING-based instruction, suggesting that the method can provide an effective structure for developing foundational numeracy. Similarly, Hayati et al. (2024) found that GASING-oriented mathematics instruction contributed to the development of students' mathematical problem-solving abilities. These findings are consistent with the present study in suggesting that GASING provides a structured learning environment in which students are encouraged to work with mathematical ideas progressively rather than relying exclusively on memorized procedures.

The contribution of the present study becomes more apparent when GASING is considered alongside contextual learning. Rosyidah and Efendi (2021); Rahmah (2021) demonstrated that contextual mathematics learning can facilitate students' mathematical connections by linking mathematical content with situations that are meaningful to learners. Such connections are particularly relevant to mathematical communication because students need to interpret a situation, identify the mathematical relationships involved, and express those relationships through words, symbols, diagrams, or other representations. Saputra (2022) likewise found that contextual teaching could produce greater gains in elementary students' mathematical communication than conventional instruction. These findings provide a theoretical and empirical basis for interpreting the present results: GASING may provide the cognitive and procedural structure needed to understand mathematical operations, whereas CTL provides meaningful situations through which students can explain why and how those operations are used.

An important distinction between the present study and much of the previous literature concerns the instructional function assigned to each approach. Earlier GASING research has frequently emphasized arithmetic competence, mathematical performance, problem solving, or general learning outcomes, whereas contextual-learning studies have often examined conceptual understanding, mathematical connections, or communication as outcomes of contextualization. The present study brings these two instructional functions together. Rather than treating GASING and CTL as competing instructional approaches, the findings indicate that their characteristics can be complementary. GASING offers a relatively systematic progression of mathematical activities, while CTL creates opportunities for students to interpret mathematical ideas within familiar situations. This combination is particularly important for mathematical communication because students are required not only to obtain an answer but also to explain the meaning of the answer, describe the strategy used, and connect symbolic procedures with contextual situations.

The findings therefore provide a more nuanced interpretation of instructional effectiveness than studies examining either GASING or CTL in isolation. The improvement observed in the present study suggests that mathematical communication may benefit when students are simultaneously supported at the level of mathematical structure and contextual meaning. The GASING component can reduce the cognitive difficulty associated with basic mathematical operations by presenting learning in a systematic and accessible sequence, while CTL can provide opportunities for students to verbalize, represent, interpret, and justify their mathematical thinking. In this sense, the contribution of the present study lies not simply in confirming that both approaches are beneficial, but in identifying a possible instructional synergy between them. The GASING–CTL integration can consequently be viewed as a model that connects procedural development with conceptual interpretation and communication, thereby extending previous research that has primarily examined these dimensions separately.

Practical and Theoretical Implications

From a practical perspective, the findings provide several implications for elementary mathematics teachers. The first is the importance of designing mathematics instruction that does not separate computational practice from meaningful mathematical communication. Teachers can use the structured characteristics of GASING to introduce mathematical operations gradually, beginning with accessible representations and guided activities before moving toward more abstract mathematical expressions. Within this structure, CTL can be used to situate mathematical tasks in familiar contexts, such as shopping, sharing objects, measuring quantities, comparing numbers, or solving problems related to students' everyday experiences. Such contextualization can help students understand that mathematical operations are not merely symbolic procedures but tools for interpreting and solving real situations.

The second implication concerns the development of mathematical communication through classroom discourse. Novianti and Wayudi (2024) demonstrated that mathematics learning designed to strengthen mathematical communication can improve students' ability to express mathematical ideas, while Dewianti (2023); Na'im and Mukhlis (2024) emphasized the importance of mathematical communication for enabling students to clarify and share their mathematical understanding. These findings suggest that teachers should deliberately incorporate opportunities for students to explain their solutions rather than treating communication as an incidental outcome of problem solving. In a GASING–CTL classroom, students can be asked to explain how they obtained an answer, describe the meaning of each operation, compare different solution strategies, or translate a contextual situation into a mathematical representation. Consequently, classroom activities should provide sufficient space for students to speak, write, draw, use symbols, and respond to the reasoning of their peers.

A third implication relates to the use of representations and learning media. Salmaini et al. (2024) showed that contextual mathematics learning supported by appropriate technological resources can contribute to students' learning outcomes, cognitive development, and engagement. Although the present study does not depend on digital technology, this finding indicates that the GASING–CTL framework can be adapted to different instructional resources. Teachers may employ concrete objects, pictures, number representations, worksheets, digital media, or interactive tasks depending on students' characteristics and the learning objectives. The essential principle is not the particular medium but the connection among representation, mathematical operation, contextual meaning, and student explanation. Thus, the model can remain flexible while retaining its central pedagogical structure.

The fourth practical implication concerns assessment. Hidayati et al. (2021) showed that mathematical communication is meaningfully related to students' mathematics learning outcomes, indicating that communication should be considered an important dimension of mathematics achievement rather than an

additional skill unrelated to content learning. Accordingly, teachers should incorporate assessment indicators that capture students' abilities to explain mathematical procedures, represent relationships, interpret answers, and communicate reasoning. This approach can also provide diagnostic information for teachers because an incorrect answer does not necessarily indicate the same type of difficulty as an incomplete explanation or an inappropriate representation. Assessment based on mathematical communication can therefore help teachers identify whether students' difficulties are conceptual, procedural, representational, or communicative.

At the theoretical level, the present findings contribute to the development of integrated instructional models that combine structured mathematical learning with contextual meaning-making. The GASING–CTL model can be conceptualized as a pedagogical bridge between cognitive structuring and contextual interpretation. GASING provides the structure through which mathematical ideas are introduced and practiced, whereas CTL provides the context through which those ideas become meaningful and communicable. The interaction between these dimensions is theoretically important because mathematical learning is not limited to acquiring correct procedures; students also need to construct meaning, connect representations, explain relationships, and use mathematical language to make their reasoning visible.

The findings also suggest that mathematical communication should not be positioned merely as an output measured after learning has occurred. Instead, communication can function as part of the learning process itself. When students are required to explain a mathematical procedure or justify an answer in a contextual situation, they are encouraged to organize their thinking, identify relationships among mathematical elements, and recognize inconsistencies in their own reasoning. The GASING–CTL model therefore has the potential to support a reciprocal relationship between understanding and communication: deeper understanding enables clearer communication, while the process of communicating mathematical ideas can further consolidate understanding. This interpretation strengthens the theoretical position that effective mathematics instruction should integrate cognitive development, contextual meaning, representation, and classroom discourse rather than treating these elements as separate instructional components.

Limitations of the Study

Despite its contributions, several limitations should be considered when interpreting the findings. First, the study was conducted with a relatively limited number of students and within a restricted number of elementary schools. Consequently, the findings should not be generalized automatically to all elementary students, particularly those who learn under substantially different curricular, socioeconomic, cultural, or institutional conditions. The effectiveness of an instructional model can depend on characteristics of the learners, teachers, schools, and learning environments in which the intervention is implemented. Therefore, further research involving larger samples and schools with greater contextual diversity is necessary to examine whether the observed advantages of the GASING–CTL integration are consistently reproduced across different educational settings.

Second, the quasi-experimental design used in the present study did not involve full individual randomization. Although the use of pretest data and statistical comparison helped establish that the groups did not differ significantly at baseline, the possibility of unmeasured differences between groups cannot be completely eliminated. Angrist et al. (2022) emphasize that differences between educational groups may reflect selection processes rather than treatment effects when assignment is not fully randomized. Similarly, the methodological literature on quasi-experimental educational research indicates that such designs can provide valuable evidence under natural school conditions but require cautious interpretation of causal claims (Miksza et al., 2023). Accordingly, the present findings should be interpreted as evidence of a statistically significant difference in learning gains associated with the GASING–CTL condition rather than as definitive proof of a causal mechanism.

Third, the duration of the intervention was relatively limited. Mathematical communication is a multidimensional competence that may require sustained opportunities for students to develop mathematical vocabulary, representation skills, explanation strategies, argumentation, and confidence in expressing mathematical reasoning. A relatively short intervention may capture immediate learning gains without fully revealing whether those gains are maintained over time. Zhang et al. (2024), through a meta-analysis of mathematics intervention studies, showed that intervention characteristics, including duration and instructional components, can influence the magnitude and variability of observed effects. Therefore, future studies should examine whether the advantages of GASING–CTL remain evident after several months or across multiple instructional units rather than only immediately following the intervention.

Fourth, the outcome measure in the present study focused primarily on students' mathematical communication performance within the scope of the instructional content. Although this provides useful

evidence of learning improvement, mathematical communication is broader than performance on a limited set of assessment tasks. It includes the ability to communicate through written and oral explanations, symbolic representations, diagrams, and interactions with peers and teachers. Longitudinal intervention research has demonstrated the value of repeated measurement for identifying learning trajectories that may not be visible through a single pretest–posttest comparison (Kong & Wang, 2023). Future research could therefore employ multiple assessment formats, classroom observations, student interviews, written work analysis, and delayed posttests to examine how students' communication develops over time and whether the observed improvement transfers to unfamiliar mathematical contexts.

Taken together, these limitations do not diminish the contribution of the study but instead clarify the boundaries within which its findings should be interpreted. The present research provides evidence that integrating GASING and CTL is associated with stronger improvement in mathematical communication than instruction using the comparison condition. Nevertheless, replication across larger and more diverse samples, longer intervention periods, and more rigorous experimental or longitudinal designs would strengthen confidence in the robustness and transferability of the findings. Future research could also examine which specific component of the integration structured GASING activities, contextual tasks, student discourse, or their interaction contributes most strongly to improvements in mathematical communication. Such research would move beyond the question of whether the integrated model works toward a more precise understanding of how, for whom, and under what conditions the GASING–CTL approach is most effective.

Conclusions

This study aimed to examine the effect of the GASING method combined with the Contextual Teaching and Learning (CTL) approach on elementary students' mathematical communication skills. Based on the findings, it can be concluded that the integration of GASING and CTL has a statistically significant positive effect on students' learning outcomes, as indicated by the higher N-Gain scores in the experimental group compared to the control group ($p = 0.006$). Although both groups showed significant improvement from pretest to posttest, the normalized learning gains confirm that the GASING–CTL combination is more effective in enhancing students' mathematical communication skills than conventional instruction. Theoretically, this study contributes to the growing body of literature on elementary mathematics education by demonstrating that the synergy between structured cognitive progression (GASING) and contextualized learning environments (CTL) strengthens students' ability to construct and communicate mathematical ideas. It extends existing research by positioning mathematical communication not only as a cognitive outcome but also as a product of the interaction between conceptual scaffolding and meaningful real-world context. Practically, the findings suggest that teachers should consider integrating GASING activities with CTL-based instructional design to support students' understanding and expression of mathematical concepts. Classroom practices should emphasize hands-on learning, contextual problem-solving, and consistent opportunities for students to explain their reasoning verbally and in written form. For policymakers, supporting teacher training programs that focus on innovative, student-centered pedagogies such as GASING and CTL is essential for improving foundational mathematics education. Future research is recommended to employ true experimental designs with randomization to strengthen causal inference, involve larger and more diverse samples to improve generalizability, and explore potential moderating variables such as prior mathematical ability, learning motivation, or teacher competency.

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