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Enhancing fourth-grade students' multiplication fluency through GASING-based mathematics instruction: A quasi-experimental study

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Abstract

Background: Multiplication fluency is fundamental to mathematical competence, yet many elementary students struggle with computational accuracy and efficiency due to their reliance on rote memorization rather than conceptual understanding.
Aims: This study investigated the effectiveness of GASING-based mathematics instruction (*Gampang, Asyik, dan Menyenangkan*) in enhancing fourth-grade students' multiplication fluency through the Kame' Bise Be' program in Pontianak, Indonesia.
Method: A quasi-experimental nonequivalent control group design involved 119 fourth-grade students, comprising an experimental group (n = 58) receiving GASING instruction from teachers trained for 15 days and a control group (n = 61) receiving conventional instruction. Data were collected using a validated 25-item timed multiplication test and analyzed using normalized gain (N-Gain), Mann–Whitney U, and Cohen's d.
Results: The experimental group achieved higher learning gains (M = 0.50, SD = 0.23) than the control group (M = 0.28, SD = 0.24), with a statistically significant difference (U = 2696.0, Z = 4.928, p < .001) and a large effect size (d = 0.91). Teacher reflections indicated improved student engagement and conceptual understanding.
Conclusion: GASING-based instruction demonstrated promising effectiveness in strengthening multiplication fluency, supporting its integration into elementary mathematics education.

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INTRODUCTION

Mathematical proficiency is a fundamental component of elementary education, providing the cognitive foundation for numerical reasoning, problem-solving, and the development of advanced mathematical competencies. Among essential arithmetic skills, multiplication fluency plays a crucial role in enabling students to perform calculations accurately and efficiently while supporting their understanding of more complex mathematical concepts (Demirci & Ergül, 2026; McNeil et al., 2025; Morano et al., 2020; Qushem et al., 2022). The development of multiplication fluency extends beyond memorizing numerical facts, requiring students to establish meaningful connections between conceptual understanding, computational procedures, and mathematical representations (Kim, 2025; McNeil et al., 2025; Torres-Peña et al., 2025). Students who have not developed automaticity in basic multiplication facts frequently experience increased cognitive demands when solving multistep mathematical problems, potentially limiting their capacity for higher-order reasoning (Van der Ven et al., 2023). Research has demonstrated that arithmetic competencies emerge through interactions among cognitive processes, procedural knowledge, and conceptual understanding, highlighting the importance of effective mathematics instruction during

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early educational stages (Chen et al., 2023). Furthermore, multiplication proficiency provides an essential foundation for subsequent mathematical topics, including division, fractions, proportional reasoning, and introductory algebra. Difficulties in mastering multiplication operations may therefore influence students' mathematical confidence, computational flexibility, and ability to solve increasingly complex problems. Although repetitive practice can facilitate arithmetic automaticity, instructional approaches that emphasize memorization without sufficient conceptual explanation may restrict students' opportunities to develop meaningful mathematical understanding. Consequently, strengthening multiplication fluency requires pedagogical strategies that integrate conceptual exploration, systematic computational practice, and progressively structured learning experiences. Developing these foundational competencies is particularly important during elementary education, when students establish mathematical knowledge and skills that influence their subsequent academic development.

Developing foundational mathematical competencies remains a significant educational challenge in Indonesia, particularly concerning students' ability to understand and apply arithmetic concepts effectively. The Programme for International Student Assessment (PISA) 2022 reported that Indonesian students achieved an average mathematics score of 366, substantially below the OECD average of 472, reflecting persistent concerns regarding national mathematical achievement (OECD, 2023). Although PISA assesses students at approximately 15 years of age, these findings reinforce the importance of strengthening mathematical learning throughout earlier educational stages. In elementary classrooms, multiplication instruction frequently involves memorizing multiplication tables and practicing computational procedures, which may not adequately support students who require additional conceptual explanations. These instructional limitations become particularly apparent when students encounter multiplication involving larger numbers, place-value relationships, and regrouping procedures that demand coordinated numerical reasoning (Bao, 2026; Kim, 2025). Preliminary interviews conducted with fourth-grade teachers participating in the GASING training program in Pontianak City, West Kalimantan, revealed persistent difficulties in students' understanding and recall of basic multiplication facts. Teachers specifically identified multiplication involving numbers six through nine as challenging because many students relied on memorized answers without understanding the underlying mathematical relationships. One participating teacher reported that multiplication difficulties persisted among some students in higher elementary grades, suggesting that existing instructional practices had not consistently established foundational arithmetic proficiency. Another teacher emphasized that students frequently struggled to explain multiplication concepts despite having previously practiced multiplication tables, indicating a potential disconnect between procedural recall and conceptual understanding. These observations highlight the need for instructional approaches that address students' computational difficulties while strengthening teachers' capacity to facilitate meaningful, engaging, and conceptually grounded mathematics learning.

The GASING method (*Gampang, Asyik, dan Menyenangkan*, meaning Easy, Fun, and Enjoyable) offers a structured instructional approach intended to improve mathematical understanding and computational proficiency through accessible, interactive, and progressively organized learning experiences. This approach integrates three interconnected instructional stages consisting of concrete exploration, abstract representation, and mental calculation, allowing students to develop mathematical understanding through a gradual transition from tangible experiences to symbolic reasoning. During the concrete stage, students manipulate instructional materials, including place-value cards and other physical representations, to visualize multiplication as repeated grouping and establish meaningful numerical relationships. The abstract stage subsequently introduces mathematical symbols and computational procedures while maintaining conceptual connections with the concrete representations previously explored. Through the mental calculation stage,

students participate in structured exercises, interactive questioning, educational games, and repetitive computational activities designed to strengthen arithmetic automaticity and multiplication fluency. This instructional progression is consistent with broader research emphasizing the importance of structured learning interventions and meaningful mathematical representations in supporting elementary students' computational development (Sleeman et al., 2021; Kling & Kline, 2025). Moreover, research on elementary mathematics interventions has highlighted the potential of engaging instructional strategies, including game-based learning and realistic mathematics education, to support mathematical achievement and student participation (Nugraheni & Marsigit, 2021; Debrenti, 2024). The effectiveness of mathematics instruction may also depend on implementation quality, as structured instructional support and teacher preparation can influence the consistency of classroom practices and students' learning experiences (Owen et al., 2021). Within the Kame' Bise Be' program in Pontianak City, GASING-based mathematics instruction was implemented by elementary school teachers who completed 15 days of intensive professional training involving conceptual instruction, teaching demonstrations, and supervised classroom practice. Accordingly, investigating GASING-based instruction within this program provides an opportunity to examine how structured mathematical representations, engaging computational activities, and teacher-supported implementation may contribute to improving multiplication fluency among fourth-grade elementary school students.

Previous studies have demonstrated the potential of diverse instructional approaches to improve mathematical proficiency among elementary school students. Research on realistic mathematics education, game-based learning, and project-based instruction has highlighted the importance of engaging learning environments in supporting mathematical understanding and achievement (Debrenti, 2024; Lazi et al., 2021; Nugraheni & Marsigit, 2021). Similarly, experimental investigations and research syntheses have examined the effectiveness of structured mathematics interventions in improving elementary students' learning outcomes (Bognar et al., 2025; Pellegrini et al., 2021). More specifically, studies on multiplication and arithmetic fluency have explored precision teaching, self-regulated learning, visual representations, and explicit instructional strategies as approaches to strengthening computational performance (Kling & Kline, 2025; Morano et al., 2020; Sleeman et al., 2021). Recent investigations have also emphasized the importance of cognitive characteristics, mathematical emotions, and individualized instructional support in explaining students' responses to arithmetic interventions (Koponen et al., 2024; McNeil et al., 2025). Furthermore, Owen et al. (2021) highlighted the relevance of implementation support in fluency-based mathematics interventions, suggesting that instructional effectiveness depends not only on pedagogical strategies but also on the quality of their implementation. Despite these contributions, the reviewed literature provides limited direct evidence concerning the comparative effectiveness of GASING-based mathematics instruction in developing multiplication fluency among fourth-grade elementary students. Existing studies have predominantly investigated broader mathematics achievement or specific fluency interventions, leaving the integrated concrete–abstract–mental-calculation sequence characteristic of GASING insufficiently examined within the selected literature. Moreover, the effectiveness of GASING instruction delivered by intensively trained teachers requires further investigation using comparative learning-gain measures and inferential statistical analysis. To address these gaps, the present study employs a quasi-experimental nonequivalent control group design to examine differences in multiplication fluency between students receiving GASING-based instruction and those experiencing conventional mathematics instruction, complemented by teachers' reflections on instructional implementation. This investigation contributes context-specific empirical evidence regarding the potential of structured GASING-based instruction to strengthen foundational arithmetic competencies in elementary mathematics education.

This study aimed to investigate the effectiveness of GASING-based mathematics instruction in enhancing multiplication fluency among fourth-grade elementary school students participating in the Kame' Bise Be' program in Pontianak City, Indonesia. Specifically, the investigation sought to compare improvements in multiplication fluency between students receiving GASING-based instruction and those participating in conventional mathematics learning activities. The study employed a quasi-experimental nonequivalent control group pretest–posttest design to examine students' mathematical performance before and after the instructional intervention. Multiplication fluency was assessed using a timed computational test designed to evaluate students' accuracy in completing multiplication operations within a predetermined duration. Changes in students' multiplication performance were quantified using normalized gain scores to provide comparative indicators of learning improvement relative to their initial achievement levels. Statistical analysis was conducted to determine whether differences in normalized learning gains between the experimental and control groups were statistically significant. Effect-size estimation was incorporated to assess the magnitude of the observed differences and provide additional information regarding the practical significance of instructional outcomes. Furthermore, qualitative evidence obtained from teacher reflection journals and interviews was examined to provide contextual insights into classroom implementation, student engagement, and teachers' perceptions of students' conceptual understanding. Through the integration of quantitative comparisons and qualitative instructional perspectives, this investigation sought to provide a comprehensive evaluation of GASING-based mathematics instruction within authentic elementary classroom environments. Ultimately, the study contributes empirical evidence concerning the potential of structured, engaging, and teacher-supported mathematics instruction to strengthen foundational multiplication fluency and inform instructional practices in elementary mathematics education.

LITERATURE REVIEW

Multiplication fluency constitutes a fundamental component of elementary mathematics education, reflecting students' ability to perform multiplication operations accurately, efficiently, and flexibly through the integration of conceptual understanding and computational proficiency. Developing this competency requires instructional approaches that move beyond mechanical memorization toward meaningful mathematical experiences that connect numerical relationships with appropriate calculation strategies. The GASING method (*Gampang, Asyik, dan Menyenangkan*, meaning Easy, Fun, and Enjoyable), developed by Yohanes Surya, represents a structured instructional approach designed to facilitate mathematical understanding through accessible, engaging, and progressively organized learning activities. Unlike conventional instruction that may introduce abstract numerical procedures before students establish sufficient conceptual foundations, GASING-based mathematics instruction emphasizes gradual transitions from concrete experiences to symbolic representations and mental computation. This approach incorporates three interconnected instructional phases consisting of concrete exploration, abstract representation, and mental calculation, each contributing to the progressive development of mathematical understanding and computational fluency. The integration of these phases provides opportunities for students to construct numerical relationships through physical manipulation before applying mathematical symbols and computational procedures. Such instructional progression shares important characteristics with the Concrete–Representational–Abstract (CRA) framework, which emphasizes systematic connections between physical materials, visual representations, and abstract mathematical concepts (Flores & Hinton, 2022). Research on mathematical cognition further suggests that the development of arithmetic fluency involves interactions among working memory,

numerical understanding, and computational automaticity (Van der Ven et al., 2023). Accordingly, GASING-based instruction offers a pedagogical framework that integrates conceptual exploration with structured computational practice to support students' mathematical development. Understanding the theoretical foundations of this approach is essential for evaluating its potential contribution to multiplication fluency among fourth-grade elementary school students.

The concrete phase represents the initial stage of GASING-based mathematics instruction, emphasizing the use of physical learning materials to facilitate students' understanding of multiplication concepts through direct mathematical experiences. During this phase, students manipulate place-value cards representing units, tens, and hundreds, allowing them to visualize multiplication as repeated grouping and establish relationships between numerical quantities. In the instructional context examined in this study, white cards represent units, black cards represent tens, and blue cards represent hundreds, providing distinct visual representations of positional numerical values. For example, the multiplication operation 3 × 12 can be demonstrated through three groups containing one tens card and two unit cards, enabling students to recognize the relationship between repeated grouping and place-value decomposition. Students subsequently combine three tens to obtain 30 and three groups of two units to obtain six, producing a final result of 36 through a conceptually structured calculation process. This instructional procedure enables students to connect physical representations with numerical operations while developing an understanding of how place value contributes to multiplication. The use of concrete mathematical materials is consistent with research emphasizing the importance of visual and spatial representations in supporting mathematical reasoning and conceptual development (Xie et al., 2020). Furthermore, structured instructional interventions involving meaningful numerical representations have been investigated as approaches to improving arithmetic performance and multiplication-related competencies (Sleeman et al., 2021; Kling & Kline, 2025). By engaging students in physical manipulation and guided mathematical exploration, the concrete phase provides opportunities to reduce dependence on memorized computational procedures and strengthen conceptual connections. Consequently, this stage establishes a representational foundation for subsequent abstract learning activities and supports the progressive development of multiplication fluency.

The abstract phase of GASING-based mathematics instruction facilitates students' transition from manipulating physical objects toward interpreting and applying mathematical symbols, numerical expressions, and written computational procedures. During this stage, students are encouraged to mentally visualize the concrete representations previously explored while translating their mathematical understanding into symbolic multiplication operations. The instructional process emphasizes place-value decomposition, enabling students to perform multiplication systematically by calculating larger positional values before combining the remaining numerical components. For instance, students solving 3 × 12 first recognize the multiplication of three tens as 30 before calculating three groups of two units as six and combining both results to obtain 36. This progression reinforces connections between conceptual understanding and procedural knowledge while encouraging students to explain the mathematical reasoning underlying their calculations. The transition from concrete representations to symbolic procedures reflects principles associated with the CRA instructional framework, which supports mathematical learning through progressively abstract forms of representation (Flores & Hinton, 2022). Research examining visual imagery in multiplication instruction has also highlighted the relevance of representational strategies for developing multiplication fact fluency and multiplicative understanding (Kling & Kline, 2025). Moreover, the GASING approach introduces multiplication facts through a deliberately structured sequence, beginning with relatively accessible operations involving 1, 10, 9, 2, and 5 before progressing toward square numbers and more challenging facts involving 3, 4, 8, 7, and 6. This progressive organization is intended to provide manageable learning challenges while strengthening

students' computational confidence and readiness for increasingly complex multiplication tasks. Therefore, the abstract phase serves as an essential instructional bridge between concrete mathematical understanding and the development of efficient mental calculation strategies.

The mental calculation phase, commonly referred to as *mencongak*, represents the final instructional stage of GASING-based mathematics learning and emphasizes the development of computational automaticity through structured and engaging practice. During this phase, students perform multiplication operations mentally and in writing through repeated exercises, interactive questioning, educational games, and rhythmic call-and-response activities designed to strengthen arithmetic fact retrieval. These activities encourage students to apply previously developed conceptual and procedural knowledge while gradually reducing their reliance on physical learning materials and written computational steps. The systematic repetition of multiplication operations is intended to improve calculation efficiency by strengthening students' ability to retrieve numerical relationships and execute computational procedures with increasing accuracy. Research on mathematical cognition indicates that arithmetic automaticity is associated with interactions among working memory, cognitive processing, and mathematical performance, highlighting the relevance of efficient computational strategies (Van der Ven et al., 2023). Similarly, investigations of multiplication fluency interventions have examined the contribution of precision teaching, structured practice, and self-regulated learning to the development of computational competencies (Sleeman et al., 2021). The incorporation of interactive learning activities also reflects broader pedagogical perspectives emphasizing the potential of game-based instruction to support students' mathematical engagement and learning experiences (Debrenti, 2024). Within GASING-based instruction, enjoyable repetition is intended to maintain students' participation while providing sufficient opportunities to consolidate multiplication facts and computational procedures. Nevertheless, the development of multiplication fluency requires maintaining meaningful connections between calculation speed, numerical accuracy, and conceptual understanding rather than emphasizing rapid responses alone. Accordingly, the mental calculation phase integrates structured computational practice with interactive learning experiences to support the consolidation of multiplication fluency among elementary school students.

The implementation of GASING-based mathematics instruction requires systematic teacher preparation to ensure that the concrete, abstract, and mental calculation phases are delivered consistently and appropriately within elementary classroom environments. In Pontianak City, West Kalimantan, the Kame' Bise Be' program, translated as *We Can*, was established through collaboration among the researchers, the GASING team, and the Pontianak City Education Office to strengthen elementary students' foundational arithmetic competencies. The program incorporates intensive professional training designed to equip teachers with the conceptual knowledge, instructional strategies, and practical competencies necessary for implementing GASING-based mathematics instruction. Participating teachers completed 15 days of structured training, conducted from 08:00 to 17:00, involving conceptual instruction, teaching demonstrations, supervised classroom practice, and direct engagement with students. This preparation emphasizes the importance of teachers' understanding of instructional sequences, appropriate selection of concrete learning materials, and effective facilitation of mathematical discussions and computational activities. Research examining implementation support in mathematics fluency interventions has highlighted the relevance of instructional guidance and implementation processes when evaluating students' mathematical learning outcomes (Owen et al., 2021). Furthermore, evidence from elementary mathematics intervention research indicates that instructional characteristics and implementation conditions should be considered when interpreting differences in mathematical achievement across learning environments (Pellegrini et al., 2021; Bognar et al., 2025). Within this framework, teacher reflection journals and interviews provide complementary information concerning instructional

implementation, student engagement, and perceived changes in students' conceptual understanding. However, evaluating GASING-based instruction requires empirical comparisons of students' multiplication performance to determine whether observed learning improvements differ from those associated with conventional mathematics instruction. Therefore, examining GASING-based mathematics instruction through a quasi-experimental approach provides an opportunity to assess its potential contribution to multiplication fluency while considering the instructional context established through structured teacher professional development.

METHOD

Research Design

This study employed a quantitative approach using a quasi-experimental design with a nonequivalent control group pretest–posttest structure (Creswell & Creswell, 2018). The design was selected to examine differences in multiplication fluency development between fourth-grade elementary school students receiving GASING-based mathematics instruction and those participating in conventional mathematics learning. Random assignment of individual students was not feasible because of school administrative constraints and the use of existing classroom arrangements. Consequently, intact classes were assigned to experimental and control conditions without randomization. Both groups completed pretest and posttest assessments to document their initial multiplication performance and subsequent learning outcomes. The pretest also enabled the researchers to identify potential baseline differences between the instructional groups, although it could not establish equivalence between them. The experimental group received GASING-based mathematics instruction delivered by teachers who had completed intensive professional training, whereas the control group followed conventional instruction based on the *Kurikulum Merdeka* mathematics teaching module. Quantitative data were collected to evaluate changes in students' multiplication fluency and compare normalized learning gains across the two instructional conditions. Additionally, qualitative information obtained from teacher reflection journals and interviews was incorporated to contextualize instructional implementation and support the interpretation of quantitative findings. This design provided a framework for examining the association between GASING-based instruction and multiplication fluency development within authentic elementary school settings.

Participants

The participants comprised 119 fourth-grade students enrolled in two public elementary schools in Pontianak City, West Kalimantan, Indonesia, namely SDN 25 Pontianak Timur and SDN 57 Kota Pontianak. The participating schools were selected purposively because they served as implementation sites for the Kame' Bise Be' program, which aimed to strengthen elementary students' arithmetic competencies through GASING-based mathematics instruction. Both schools had teachers who participated in intensive GASING professional training before classroom implementation. The experimental group consisted of 58 students distributed across two existing classes, with one class selected from each participating school. These students received multiplication instruction using the GASING method delivered by teachers who had completed the designated training program. The control group comprised 61 students from two existing classes at SDN 25 Pontianak Timur who received conventional mathematics instruction based on the *Kurikulum Merdeka* teaching module. The sample included students with diverse learning characteristics and educational needs, including six students experiencing reading-fluency difficulties and one student with special educational needs in the experimental group. These students remained included in the instructional activities and assessments in accordance with the study's

inclusive classroom approach. Official research permission was obtained from the principals of both participating schools before the study commenced, and information about the research was communicated to parents or guardians through the schools' established communication channels. Written parental or guardian consent was subsequently collected through an online form after data collection had been completed, with responses obtained from parents or guardians of students in two participating classes.

Instruments and Data Collection

The primary research instrument was a timed multiplication test developed to assess fourth-grade students' rapid calculation performance through a combination of computational accuracy and completion within a predetermined time limit. The instrument consisted of 25 multiplication items representing four categories of computational complexity: eight single-digit by single-digit multiplication items, eight two-digit by single-digit multiplication items, five two-digit by two-digit multiplication items, and four three-digit by single-digit multiplication items, including operations involving zero. The items were presented in randomized order to reduce predictable sequencing across different levels of computational difficulty. Students were allocated 15 minutes to complete the assessment, and each correct response received one point, producing a maximum possible score of 25. The same scoring procedure was applied to the pretest and posttest assessments to support comparisons of multiplication performance before and after the instructional intervention.

Content validity was evaluated through expert judgment involving one mathematics education lecturer and one experienced elementary school mathematics teacher. Both validators assessed the relevance and essentiality of the multiplication items, and the original instrument evaluation reported a Content Validity Ratio (CVR) of 0.87. Instrument reliability was examined through a preliminary trial involving 30 fourth-grade students from another elementary school that was not included in the main study. The pilot assessment produced a Cronbach's alpha coefficient of 0.81, indicating satisfactory internal consistency for the multiplication test. Quantitative data were obtained from students' pretest and posttest scores, whereas qualitative data were collected through teacher reflection journals and interviews conducted in connection with the GASING training and classroom implementation activities. The qualitative instruments were intended to capture teachers' experiences in implementing the instructional stages, their observations of student engagement, and their perceptions of students' developing conceptual understanding and computational proficiency.

Data Analysis

Quantitative data were analyzed using descriptive and inferential statistical procedures to examine multiplication fluency development and differences in learning outcomes between the experimental and control groups. Descriptive statistics, including means and standard deviations, were calculated to summarize students' pretest scores, posttest scores, and normalized learning gains. Individual learning improvements were evaluated using the normalized gain (N-Gain) formula introduced by Hake (1998), expressed as follows:

$$g = \frac{Spost - Spre}{Smax - Spre}$$

where g represents the normalized gain score, *Spost* denotes the posttest score, *Spre* represents the pretest score, and *Smax* indicates the maximum possible score of 25. The N-Gain scores were classified into three categories based on Hake (1998): high improvement ($g>0.70$), moderate improvement ($0.30<g\leq0.70$), and low improvement ($g\leq0.30$). These classifications were used to describe the relative magnitude of students' learning improvements across the two instructional conditions.

Before conducting inferential analysis, the distributional characteristics of the data were examined using the Shapiro–Wilk normality test, while the homogeneity of variance was assessed using Levene's test. The statistical significance threshold was established at $\alpha=0.05$. Because the normality assumption was violated in the control group ($p<0.001$), the Mann–Whitney U test was selected as the primary nonparametric procedure for comparing normalized learning gains between the experimental and control groups. The analysis employed a two-tailed hypothesis test to determine whether the distributions of learning gains differed significantly between the instructional conditions. The magnitude of the observed between-group difference was additionally estimated using Cohen's d, calculated using the pooled standard deviation. Effect sizes were interpreted according to the thresholds specified in the original analytical framework: small ($d<0.50$), medium ($0.50\leq d<0.80$), and large ($d\geq0.80$). All quantitative analyses were conducted using Python version 3.12 with SciPy version 1.11.

Qualitative information obtained from teacher reflection journals and interviews was examined using a descriptive thematic approach. The analysis involved reviewing teachers' statements, identifying recurring instructional experiences, and organizing relevant observations into themes associated with conceptual understanding, computational strategies, student engagement, and classroom implementation. These qualitative findings were used to contextualize the quantitative results rather than establish independent causal evidence of instructional effectiveness. Integrating both forms of evidence provided additional information concerning how GASING-based mathematics instruction was implemented and experienced by participating teachers.

Research Procedure

The research procedure consisted of teacher preparation, preliminary assessment, instructional implementation, post-intervention assessment, and data analysis. Before the classroom intervention, teachers assigned to the experimental group participated in 15 days of intensive GASING professional training conducted through the Kame' Bise Be' program in Pontianak City. The training sessions were scheduled from 08:00 to 17:00 and were facilitated by the researcher as the lead trainer, assisted by members of the GASING instructional team. Training activities emphasized three principal components: conceptual mastery of the GASING instructional sequence, demonstration and guided practice of teaching techniques, and supervised instructional experiences involving elementary school students. The participating teachers also received a GASING teaching guidebook prepared by the researcher, which provided structured instructional guidance covering place value, addition, multiplication, and related mathematical concepts. The training was intended to strengthen teachers' understanding of the concrete–abstract–mental-calculation sequence and support consistent implementation during subsequent classroom activities.

Following teacher preparation, students in both instructional groups completed a pretest to establish their initial multiplication performance. The classroom intervention was subsequently implemented over three weeks in November 2025, consisting of six instructional sessions, with two sessions conducted each week. Each session lasted approximately 70 minutes, resulting in a total instructional duration of 420 minutes per group. The learning materials were aligned with the *Kurikulum Merdeka* Phase B mathematics curriculum for fourth-grade elementary students. Instruction focused on single-digit by single-digit multiplication, two-digit by single-digit multiplication with and without regrouping, two-digit by two-digit multiplication, and three-digit by single-digit multiplication.

In the experimental group, multiplication instruction followed the three sequential stages of the GASING method: concrete exploration, abstract representation, and mental calculation. During the concrete phase, students manipulated physical learning materials, including place-value cards and transparent plastic cups, to represent multiplication through repeated grouping and positional

numerical relationships. White cards represented units, black cards represented tens, and blue cards represented hundreds, enabling students to distinguish numerical values through visual and physical representations. For example, multiplication involving two-digit numbers was introduced through grouping activities that allowed students to identify tens and units before performing numerical calculations. During the abstract phase, students translated these concrete representations into mathematical symbols and written computational procedures while explaining the reasoning underlying each calculation. The mental calculation phase subsequently involved structured computational practice, oral questioning, educational games, and interactive repetition intended to strengthen multiplication fact retrieval and calculation efficiency.

The classroom implementation at SDN 25 Pontianak Timur included the use of transparent plastic cups as concrete instructional materials for representing multidigit multiplication. Students were guided to connect the physical grouping activities with written multiplication procedures presented on the classroom whiteboard. This instructional process illustrated the transition from concrete mathematical exploration to abstract computational representation.



Figure 1. A teacher uses concrete media (plastic cups) in the concrete phase of multiplication instruction at SDN 25 Pontianak Timur.

At the other participating school, GASING-based instruction incorporated place-value cards to support students' understanding of multiplication through repeated grouping and numerical decomposition. Students actively participated in representing units, tens, and hundreds using differently colored cards before translating these representations into mathematical expressions. These activities were intended to strengthen students' understanding of positional values while supporting their transition toward abstract and mental multiplication procedures.



Figure 2. Students hold place-value cards during the concrete phase of GASING-based multiplication instruction.

Meanwhile, students in the control group received conventional mathematics instruction using the same *Kurikulum Merdeka* Mathematics Teaching Module for Phase B, Grade IV, without GASING-based modifications. Instruction primarily involved direct teacher explanations, worked examples from textbooks, and individual written exercises. Both groups studied comparable multiplication content over the same instructional period, although the instructional approaches differed. Classroom implementation was monitored using observation sheets completed by peer teachers from the participating schools who served as research assistants. These observations were intended to document instructional activities and assess adherence to the designated teaching procedures.

After the intervention, students in both groups completed the multiplication posttest using the established assessment and scoring procedures. Pretest and posttest scores were subsequently processed to calculate normalized learning gains and compare instructional outcomes. Teacher reflection journals and interviews were also examined to identify recurring observations concerning student engagement, conceptual understanding, and computational development. Finally, quantitative and qualitative findings were considered together to provide a contextualized interpretation of multiplication fluency development following GASING-based and conventional mathematics instruction.

RESULTS AND DISCUSSION

Results

Table 2 presents complete descriptive statistics for both groups. The experimental group's pretest score (M = 2.33, SD = 2.49, Mdn = 2.00) was lower than the control group's (M = 5.33, SD = 4.97, Mdn = 4.00). This difference reflects unequal baseline conditions between the two groups — an inherent limitation of the non-random design that must be considered in interpretation. The low pretest scores in both groups (highest 12 out of 25 points) confirm that students indeed lacked adequate calculation fluency before the intervention.

Table 2. Descriptive Statistics of Rapid Multiplication Calculation Ability

Statistic	Experimental Group (n = 58)	Control Group (n = 61)
Pretest M (SD)	2.33 (2.49)	5.33 (4.97)
Pretest Median	2.00	4.00
Pretest Min–Max	0–10	0–17
Posttest M (SD)	13.64 (5.24)	10.84 (5.80)
Posttest Median	14.00	11.00
Posttest Min–Max	3–25	1–23
N-Gain M (SD)	0.50 (0.23)	0.28 (0.24)
N-Gain Median	0.53	0.27
N-Gain Category	Medium	Low

Note. Maximum score = 25. N-Gain categories based on Hake (1998).

Although the experimental group had lower pretest scores, their posttest performance (M = 13.64) substantially exceeded the control group's (M = 10.84). This represents an absolute gain of 11.31 points for the experimental group, compared to 5.51 points for the control group. The higher N-Gain in the experimental group (0.50 vs. 0.28) indicates that their improvement was far greater relative to their initial ability.

Table 3. Assumption and Hypothesis Test Results

Statistical Test	Value	p	Interpretation
Shapiro–Wilk (Exp.)	W = 0.976	0.308	Normally distributed
Shapiro–Wilk (Control)	W = 0.902	< 0.001	Not normal (use non-parametric)
Levene's Test	F = 0.075	0.785	Homogeneous variance
Mann–Whitney U	U = 2696.0; Z = 4.928	< 0.001	H0 rejected (significant)
Cohen's d	d = 0.91	—	Large effect size

Note. All tests two-tailed; $\alpha = 0.05$.

Table 3 summarizes the assumption-test results. The Shapiro–Wilk test showed that the experimental group's N-Gain was normally distributed (W = 0.976, p = .308), but the control group's distribution deviated significantly from normality (W = 0.902, p < .001). Non-normality in the control group was likely due to greater ability variation within that group, consistent with the larger SD in the posttest (5.80 vs. 5.24). Levene's test confirmed homogeneity of variance (F = 0.075, p = .785). Because normality was violated in one group, the Mann–Whitney U test was chosen as the primary hypothesis test.

The Mann–Whitney U test yielded a statistically significant difference between the experimental and control groups in rapid multiplication N-Gain scores (U = 2696.0, Z = 4.928, p < .001, two-tailed). Thus, the null hypothesis (no difference in N-Gain between the two groups) was rejected. The effect size Cohen's d = 0.91 indicates a large effect, meaning the experimental group's N-Gain distribution was approximately 0.91 standard deviations above the control group's. Using standard conversion, this is equivalent to the experimental group outperforming the control group at approximately the 82nd percentile of the control distribution.

Implementing teachers' reflection journals provided qualitative confirmation of the quantitative findings. Respondent 1 noted in their reflection journal regarding 2-digit × 1-digit multiplication material:

> *"This multiplication session, especially 2-digit by 1-digit multiplication, went smoothly and was truly enjoyable because it was easier using the GASING method — they were quick and found it easy, especially for multiplication of 2 digits by simple numbers." (Respondent 1, Reflection Journal, 2025)*

Respondent 2 also noted in their reflection journal:

> *"I realized that concrete media such as unit sticks greatly helped students understand the addition process." (Respondent 2, Reflection Journal, 2025)*

Both teachers also identified areas for improvement: Respondent 1 noted the need for extra attention for students with special needs, while Respondent 2 noted the need to slow the pace of explanation for the carrying/regrouping portion and add more contextual practice (word problems) — a need consistent with the literature showing that transferring calculation fluency to word problems requires its own explicit practice (Verschaffel et al., 2020). These notes indicate high pedagogical reflectivity and implementation consistency.

Figure 3 shows written classroom activity, where students at SDN 57 worked on problems on a large whiteboard. The board displays the three GASING phases (Concrete, Abstract, Mental Calculation) and 2-digit multiplication problems, reflecting the fidelity of the learning sequence.

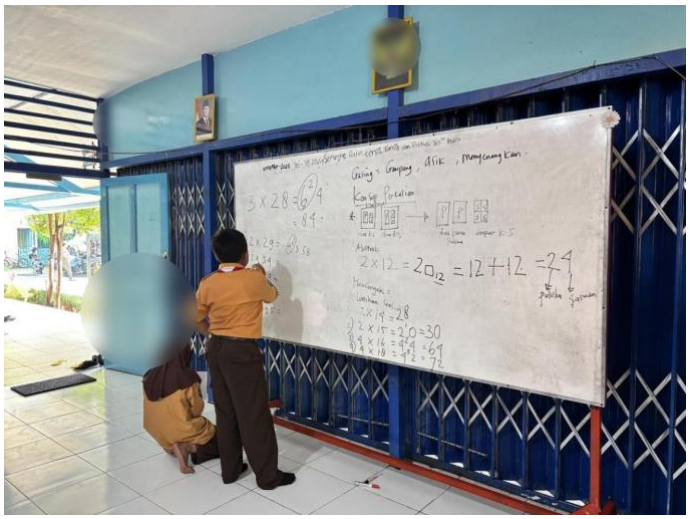


Figure 3. Students work on multiplication problems on a large board during the abstract phase (SDN 25 Pontianak Timur, November 2025)

Figure 4 shows students' enthusiasm in following GASING instruction, with many students raising their hands to answer the teacher's questions — in contrast to conventional instruction, where active student participation tended to be lower.



Figure 4. Students enthusiastically raise their hands to answer during a mental-calculation question-and-answer session (SDN 57 Kota Pontianak, November 2025)

Discussion

The large and statistically significant N-Gain advantage of the GASING group (d = 0.91) places this intervention among the most effective arithmetic-fluency development programs in the literature. Referring to Graves and Stringer's (2024) meta-analysis of mathematics interventions in elementary schools, an effect size of this magnitude is classified as above average (average d = 0.41) and can be considered practically, not merely statistically, significant. This finding confirms and strengthens the results of Puspitasari et al. (2026) and Sihombing et al. (2026), who reported GASING's effectiveness in improving multiplication learning outcomes, while providing more methodologically rigorous evidence (a control-group design, rather than a single-group pretest–posttest only). Several theoretical mechanisms explain the GASING group's advantage.

Cognitive load reduction through concrete scaffolding. GASING's concrete phase, using place-value cards, allows students to build an accurate mental model of multiplication before transitioning to numerical abstraction. This directly reduces extraneous cognitive load — load irrelevant to the learning itself — consistent with Cognitive Load Theory (Friso-van den Bos et al., 2013). Once the mental model is established, transitioning to the abstract phase becomes much easier because students do not have to process concepts and symbols simultaneously.

Automaticity through enjoyable structured drilling. GASING's mental-calculation phase, with oral drilling, call-and-response songs ("berapa berapa?"), and games, builds automaticity of multiplication facts through repetition that does not feel burdensome. This automaticity frees working-memory capacity for use in more complex cognitive tasks (Van der Ven et al., 2023). Findings from educational neuroscience further support the idea that structured instruction can produce the cognitive changes underlying such automaticity (Sokolowski & Ansari, 2018), while repeated, self-directed drilling through games also trains students' self-regulation in learning, which is empirically correlated with academic achievement (Dent & Koenka, 2016). Respondent 1 noted that students were "quick and found it easy" with simple multiplication — a description that precisely matches the definition of arithmetic automaticity.

Material sequencing that optimizes confidence. GASING does not teach multiplication sequentially from 1–10, but rather from easiest first (multiplication by 1, 10, 9, 2, 5, square numbers, 3, 4, 8, 7, 6). This sequence ensures students experience success from the outset, building confidence and reducing math anxiety (Ramirez et al., 2018; Namkung et al., 2019). Respondent 4, in an interview, cited this as one of the most important "aha moments": "Multiplication doesn't start with memorization alone… and the sequence of material in GASING for multiplication isn't ordered from 1–10, but starts with the easiest multiplication first." (Respondent 4, interview, 2025)

Quality of teacher training as a multiplier effect. The 15-day training, which included hands-on practice teaching real students, built substantial teacher pedagogical confidence. Respondent 3 stated after the training: "I am much more confident now because the steps are clear and structured, and I have seen for myself that students find it easier to follow along when given drills, games, and the right concrete stages" (Respondent 3, interview, 2025). Teacher confidence has been shown to influence implementation quality and, through it, student learning outcomes (Blazar & Kraft, 2017). This explains why the GASING effect in this study was larger than in some previous studies that did not include structured teacher training.

Implications

The control group achieved only a low N-Gain category (M = 0.28), despite starting with higher pretest scores and using a standardized Kurikulum Merdeka teaching module. This indicates that the availability of a good curriculum is insufficient without an effective pedagogical approach to teaching multiplication fluency. This finding is consistent with Fuchs et al. (2010), who emphasized

that developing arithmetic-fact fluency requires explicit, structured instruction accompanied by adequate practice — a component lacking in lecture-based conventional instruction. The higher variability in control-group N-Gain (SD = 0.24 vs. 0.23) indicates that conventional instruction produced uneven results: some students improved rapidly, while others remained nearly stagnant. In contrast, the GASING method produced more even improvement across initial ability levels, indicating its potential as an effective inclusive approach (Bouck & Park, 2018). One of the most interesting findings is that the experimental group, which started with lower pretest scores (M = 2.33 vs. 5.33), was able to achieve higher posttest scores (M = 13.64 vs. 10.84). This shows that the GASING method is highly effective for students with low prior knowledge — a finding relevant from an educational-equity perspective. Fuchs et al. (2010) found that explicit, structured instruction is particularly beneficial for students lacking informal mathematical knowledge. GASING, with its highly structured concrete–abstract–mental-calculation stages, meets this criterion. This is also consistent with findings that immediate feedback during drilling benefits students with lower prior knowledge the most (Fyfe & Rittle-Johnson, 2016).

Limitations and Suggestions for Future Research

This study has several methodological and contextual limitations that should be considered when interpreting the effectiveness of GASING-based mathematics instruction in improving fourth-grade students' multiplication fluency. First, the quasi-experimental design employed nonrandom assignment of intact classes, resulting in baseline differences between the experimental and control groups that could not be fully controlled and may have influenced the observed learning gains. Second, the three-week intervention period, comprising six instructional sessions, restricted the evaluation to short-term improvements and did not provide evidence regarding the long-term retention of multiplication fluency. Third, the investigation involved only two public elementary schools in Pontianak City, West Kalimantan, thereby limiting the generalizability of the findings to other educational settings, student populations, and instructional environments. Fourth, the experimental group included students with reading-fluency difficulties and special educational needs, whose inclusion supported equitable educational participation but introduced learner-related variability that should be considered when interpreting instructional outcomes. Fifth, qualitative evidence was constrained by incomplete teacher reflection journals and interviews involving teachers beyond the participating research schools, potentially limiting the consistency and direct relevance of qualitative triangulation. Sixth, although institutional permission was obtained before implementation, parental or guardian consent was collected retrospectively from only two participating classes, representing an important ethical limitation that future investigations must address through prospective informed-consent procedures. To overcome these limitations, subsequent research should employ randomized or carefully matched comparison groups, account for baseline achievement differences, and consider potential teacher- and school-level influences when evaluating instructional effectiveness. Longitudinal investigations incorporating follow-up assessments three to six months after intervention are also recommended to determine whether improvements in multiplication fluency are sustained beyond the immediate instructional period. Future studies should additionally involve larger and more geographically diverse samples, examine GASING-based instruction across arithmetic competencies such as division and multidigit addition, and conduct subgroup analyses to evaluate its suitability for students with different learning characteristics and special educational needs. From a practical perspective, expanding intensive GASING teacher training across elementary schools in West Kalimantan and exploring its integration into regular mathematics instruction for grades III–V may be beneficial, provided that implementation quality and learning outcomes are systematically evaluated. Ultimately, future research should combine stronger experimental controls, comprehensive ethical safeguards,

systematic qualitative documentation, and extended outcome assessments to establish more robust evidence regarding the effectiveness, sustainability, and inclusiveness of GASING-based mathematics instruction.

CONCLUSION

This study provides rigorous empirical evidence that the GASING method, implemented by teachers who completed 15 days of intensive training under the Kame' Bise Be' program, significantly and substantially improved fourth-grade elementary students' rapid multiplication calculation ability in Pontianak City (Mann–Whitney U = 2696.0, Z = 4.928, $p < .001$; Cohen's d = 0.91). The experimental group achieved a medium N-Gain category (M = 0.50) compared to a low category in the control group (M = 0.28). Qualitative data from teacher reflection journals and interviews confirmed that the concrete–abstract–mental-calculation stages, use of place-value card media, and the enjoyable dimension (drilling through games and songs) contributed to increased student enthusiasm and conceptual understanding.

AUTHOR CONTRIBUTIONS STATEMENT

Frilly Charolin Rengkuan contributed to the conceptualization, research design, methodology, investigation, implementation of GASING-based mathematics instruction, teacher training, data collection, formal analysis, and preparation of the original manuscript draft. Elah Nurlaelah contributed to the conceptualization, methodological development, research supervision, validation, interpretation of findings, and critical review and editing of the manuscript. Endang Cahya Mulyaning A contributed to methodological refinement, instrument validation, data interpretation, research supervision, and manuscript review and editing. All authors contributed to the evaluation of GASING-based mathematics instruction within the Kame' Bise Be' program, critically reviewed the manuscript, and approved the final version for publication.

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