

TRANSFORMING ELEMENTARY MATHEMATICS INSTRUCTION IN REMOTE INDONESIA: A COMPARATIVE EFFECTIVENESS STUDY OF GASING METHOD PROFESSIONAL DEVELOPMENT ACROSS COASTAL AND HIGHLAND REGIONS

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ABSTRAK

Kesenjangan kompetensi matematis guru sekolah dasar di wilayah terpencil menjadi tantangan bagi pemerataan kualitas pendidikan di Indonesia. Penelitian ini bertujuan mengevaluasi efektivitas pelatihan intensif metode GASING (*Gampang, Asyik, dan Menyenangkan*) dalam meningkatkan pengetahuan pedagogis matematis guru pada konteks geografis yang berbeda. Penelitian menggunakan desain kuasi-eksperimental *pretest-posttest* tanpa kelompok kontrol, melibatkan 80 guru sekolah dasar, terdiri atas 32 guru dari Kepulauan Sangihe dan 48 guru dari Pegunungan Jayawijaya. Pelatihan berlangsung selama 2–3 minggu dengan materi lima domain aritmetika. Data dianalisis menggunakan statistik deskriptif, uji-t, dan ukuran efek Cohen's *d*. Hasil menunjukkan perbedaan kompetensi awal yang signifikan antara Sangihe (57,38) dan Jayawijaya (16,33; $p < 0,001$). Setelah pelatihan, skor rata-rata meningkat menjadi 98,81 dan 82,63. Jayawijaya mencatat peningkatan absolut lebih besar, yakni 66,29 poin, dibandingkan Sangihe sebesar 41,44 poin. Temuan ini menunjukkan potensi pelatihan GASING untuk memperkuat kompetensi guru di wilayah dengan keterbatasan sumber daya. Namun, kesenjangan pascapelatihan menegaskan perlunya pendampingan berkelanjutan dan pengembangan profesional yang responsif terhadap konteks lokal

Kata kunci: metode GASING; kompetensi matematis guru; pengembangan profesional; pemerataan pendidikan; sekolah dasar

ABSTRACT

Disparities in elementary teachers' mathematical competence remain a challenge to educational equity in geographically isolated regions of Indonesia. This study aimed to evaluate the effectiveness of intensive professional development using the GASING (*Gampang, Asyik, dan Menyenangkan*) method in improving teachers' mathematical pedagogical knowledge across contrasting geographical settings. A quasi-experimental pretest–posttest design without a control group involved 80 elementary teachers, comprising 32 from the Sangihe Islands and 48 from the Jayawijaya Highlands. The intervention lasted 2–3 weeks and covered five arithmetic competency domains. Data were analyzed using descriptive statistics, *t*-tests, and Cohen's *d* effect sizes. The results revealed a significant baseline disparity between Sangihe (57.38) and Jayawijaya (16.33; $p < .001$). Following training, mean scores increased to 98.81 and 82.63, respectively. Jayawijaya teachers achieved a greater absolute gain of 66.29 points, compared with 41.44 points in Sangihe. These findings indicate the potential of GASING-based professional development to strengthen teachers' competence in resource-constrained settings. Nevertheless, the remaining post-intervention gap highlights the need for sustained mentoring and context-responsive professional learning to support long-term improvements in mathematics instruction and educational equity.

Keywords: GASING method; teachers' mathematical competence; professional development; educational equity; elementary education

INTRODUCTION

Mathematics education at the elementary level plays a fundamental role in developing students' numeracy, logical reasoning, and problem-solving abilities. The quality of these learning experiences depends not only on curriculum and instructional materials but also on teachers' mastery of mathematical concepts and their ability to translate that knowledge into meaningful classroom practice. Teachers need adequate content knowledge and *pedagogical content knowledge* (PCK) to select appropriate representations, anticipate students' misconceptions, and explain mathematical procedures in ways that support conceptual understanding. Research has shown that mathematical content knowledge, PCK, and teachers' ability to recognize students' mathematical thinking are related but distinct dimensions of teaching expertise (Copur-Gencturk & Tolar, 2022). Similarly, studies examining mathematics teachers' PCK demonstrate the importance of subject-specific pedagogical competence in organizing and delivering mathematics instruction (Barut et al., 2021; Ekawati et al., 2022; Kurniadi et al., 2022). Therefore, strengthening teachers' mathematical competence is an essential step toward improving instructional quality and expanding equitable learning opportunities for elementary school students.

Professional development is one strategy for strengthening teachers' mathematical knowledge and improving their instructional practices. However, the effectiveness of professional development depends on more than participation in training activities. Programs need to address specific subject matter, provide opportunities for active learning, connect conceptual understanding with instructional practice, and support teachers in applying what they have learned. A systematic review by Rosli and Aliwee (2021) highlights the importance of professional development in mathematics education, while Johari et al. (2022) examine the contribution of integrated professional development to mathematics teachers' learning. Evidence from lesson study research further indicates that teachers' knowledge and practice can develop through collaborative planning, classroom observation, and reflection on instructional decisions (Benedict et al., 2023; Ding et al., 2023). These findings suggest that professional development should be evaluated through measurable changes in teachers' knowledge rather than attendance or completion alone. They also raise an important question: whether the same professional development intervention can produce meaningful improvements when implemented among teachers with different levels of initial competence and in contrasting educational environments.

This question is particularly important in Indonesia, where geographical conditions and unequal access to educational resources create challenges for providing consistent professional learning opportunities. Teachers working in geographically isolated areas may face constraints in accessing training, instructional materials, mentoring, and continuing professional support. Such conditions make educational equity a matter not only of distributing educational services but also of ensuring that teachers have sufficient opportunities to develop the knowledge required for effective instruction. Research on mathematics teacher competence emphasizes the relationship between teachers' mathematical knowledge and their instructional capacity (Barut et al., 2021; Copur-Gencturk & Tolar, 2022). Nevertheless, the implications of these findings for geographically diverse regions require closer examination. In particular, differences in teachers' initial mathematical competence should be measured directly rather than assumed from their geographical location. A comparative assessment can clarify the magnitude of existing disparities, identify specific areas of weakness, and establish whether targeted professional development can help reduce the distance between teachers' starting points and the expected level of competence.

One instructional approach that warrants investigation in this context is the GASING method, an acronym for *Gampang, Asyik, dan Menyenangkan* (easy, enjoyable, and fun). GASING emphasizes structured arithmetic learning through concrete activities, visual representations, numerical patterns, and progressively developed calculation strategies. Its instructional principles are relevant to the *concrete–pictorial–abstract* (CPA) approach, which facilitates the transition from manipulating objects to interpreting visual models and working with mathematical symbols. A systematic review by Azzumar and Juandi (2023) examines the application of CPA approaches in mathematics education, while Lutfi and Dasari (2024) map research trends concerning this approach. These studies provide a pedagogical basis for examining structured, representation-based arithmetic instruction as a means of strengthening conceptual understanding. In teacher professional development, such an approach may also help participants understand not only how to perform calculations but also how to explain mathematical relationships and select instructional strategies appropriate to students' needs.

Empirical research has increasingly examined GASING in elementary mathematics education, particularly in relation to arithmetic performance and conceptual understanding. Maulida et al. (2024) examined its application with the *teams games tournament* (TGT) cooperative learning model to support understanding of two-digit multiplication. Ramadhanti et al. (2024) studied the use of GASING for two-digit addition, and Yuliyanto et al. (2024) examined its application to multiplication skills among third-grade elementary students. More recent studies have explored the use of GASING in multiplication-based learning activities (Adam et al., 2026), numeracy improvement in elementary education (Gesiradja et al., 2026; Yuana et al., 2026), and numeracy development in school-based community interventions (Resky et al., 2025). Waimbo et al. (2026) also examined GASING as an intervention for improving arithmetic fluency in an under-resourced community context. Taken together, these studies indicate growing interest in GASING as an approach to strengthening foundational mathematics learning across different settings.

Despite this growing body of evidence, an important distinction remains between improving students' mathematical performance and improving teachers' own mathematical and pedagogical competence. Positive student outcomes do not automatically establish that teachers have developed a deeper understanding of arithmetic concepts or become better equipped to explain different solution strategies. Likewise, findings from a single school or region cannot establish whether an intervention produces comparable results in locations with substantially different starting conditions. Although research has examined GASING in several instructional contexts, comparative evidence on teachers' domain-specific knowledge gains across geographically contrasting regions remains limited. Research on mathematics teacher development also highlights the importance of examining how professional learning translates into changes in teachers' knowledge and practice (Benedict et al., 2023; Ding et al., 2023). Consequently, the effectiveness of GASING-based professional development needs to be assessed directly at the teacher level, with attention to baseline disparities, post-training achievement, and differences in improvement across arithmetic domains.

The present study addresses this gap by evaluating intensive GASING-based professional development among elementary school teachers in two geographically contrasting locations: the Sangihe Islands in North Sulawesi and the Jayawijaya Highlands in Papua. These settings provide an opportunity to examine whether a common training program can support teacher learning under different geographical and educational conditions. The study assesses teachers' knowledge across five arithmetic competency domains: *Bakal Kubagi* (foundational multiplication and division concepts), addition, multiplication, subtraction, and division. This

domain-specific analysis is important because overall scores may conceal differences in teachers' understanding of individual operations. By comparing baseline scores, post-intervention results, absolute gains, relative improvements, and effect sizes, the study seeks to provide a more comprehensive account of how teacher learning varies according to initial competence and regional context.

Accordingly, this study aims to evaluate the effectiveness of intensive GASING professional development in improving elementary teachers' arithmetic pedagogical knowledge across the Sangihe Islands and the Jayawijaya Highlands. Three research questions guide the investigation: (1) What differences exist in teachers' baseline arithmetic pedagogical knowledge between the two regions, and how are these differences reflected across the five competency domains? (2) To what extent does intensive GASING training improve teachers' knowledge in each region, as indicated by absolute gains, relative improvements, and effect sizes? (3) How do learning gains vary across the five arithmetic domains, and what do these patterns reveal about the relationship between initial competence and professional development outcomes? By addressing these questions, the study contributes comparative evidence on teacher-focused mathematics professional development and offers practical insights for designing more equitable, context-responsive training programs for geographically isolated educational communities.

METHODS

This study employed a quasi-experimental pretest–posttest design without randomization or a control group to examine changes in teachers' arithmetic pedagogical knowledge following intensive professional development using the GASING method. The study was conducted in the Sangihe Islands, North Sulawesi (June 18–July 4, 2025), and the Jayawijaya Highlands, Papua (December 5–22, 2025), representing distinct geographical and educational contexts in Indonesia. Both regions received the same instructional framework covering five arithmetic competency domains.

The participants were 80 elementary school teachers recruited through convenience sampling in collaboration with district education offices, comprising 32 teachers from Sangihe and 48 from Jayawijaya. Eligible participants were actively teaching mathematics in grades 1–6, willing to attend the intensive training, and provided informed consent. Teaching experience ranged from 2 to 28 years ($M = 12.4$, $SD = 6.8$). Of the participants, 62.5% held undergraduate degrees in education, while 37.5% held diplomas or equivalent qualifications. All participants completed the training.

The intervention consisted of 45–60 hours of intensive GASING (*Gampang, Asyik, dan Menyenangkan*) training delivered by three certified master trainers over approximately 2–3 weeks. The program addressed five competency domains: *Bakal Kubagi*, addition, multiplication, subtraction, and division. Instruction followed a concrete–pictorial–abstract (CPA) progression, integrating manipulatives, visual representations, mathematical symbols, mental calculation, number decomposition, and conceptual reasoning. Activities included demonstrations, guided practice, immediate feedback, peer teaching, and reflection. Local examples, such as sweet potato calculations in Jayawijaya and fishing yields in Sangihe, were incorporated to contextualize arithmetic learning.

Teachers' arithmetic pedagogical knowledge was measured using standardized, criterion-referenced tests developed by the GASING program developers. Separate tests assessed each competency domain, with scores ranging from 0 to 100. Items measured procedural calculation skills and conceptual understanding of mathematical strategies and

reasoning. The instruments had been piloted with more than 200 Indonesian teachers, yielding Cronbach's alpha coefficients of 0.82–0.89. Pretests were administered immediately before training and posttests on the final training day. Assessments were conducted in Bahasa Indonesia, with clarification in local languages when necessary, following standardized administration procedures.

Descriptive statistics (means and standard deviations) summarized scores by region and competency domain. Independent-samples *t*-tests compared baseline scores between regions, while paired-samples *t*-tests examined pretest–posttest changes within each region. Absolute learning gains were calculated by subtracting pretest scores from posttest scores, and relative improvement was expressed as a percentage of baseline scores. Cohen's *d* was used to estimate effect sizes, with values of 0.2, 0.5, and 0.8 representing small, medium, and large effects, respectively (Cohen, 1988). Analyses covered individual domains and overall performance, using a significance level of $\alpha = 0.05$. All analyses were conducted in Python 3.9 using NumPy, SciPy, and Pandas. Given the absence of randomization and a control group, findings were interpreted as observed changes following training rather than definitive causal effects.

The study received approval from the relevant institutional review board and followed the principles of the Declaration of Helsinki. Participation was voluntary, and informed consent was obtained from all teachers before data collection.

RESULTS AND DISCUSSION

Results

Baseline Disparities in Teachers' Arithmetic Knowledge

The baseline assessment was conducted to identify differences in teachers' arithmetic knowledge before the implementation of GASING-based professional development. The results showed a substantial disparity between teachers in the Sangihe Islands and the Jayawijaya Highlands, both in overall performance and across the five competency domains. Sangihe teachers obtained a mean overall score of 57.38 (SD = 20.12), whereas Jayawijaya teachers obtained a mean score of 16.33 (SD = 11.84). The difference between the regional means was 41.05 points, indicating that the two groups entered the training with markedly different levels of arithmetic knowledge.

Table 1. Baseline Teachers' Arithmetic Knowledge by Domain and Region

Competency Domain	Sangihe Mean	Sangihe SD	Jayawijaya Mean	Jayawijaya SD	Mean Difference	p-value
Bakal Kubagi	47.81	9.58	13.54	18.16	34.27	<0.001
Addition	85.94	15.63	31.67	38.56	54.27	<0.001
Multiplication	47.50	13.20	13.96	19.21	33.54	<0.001
Subtraction	67.19	16.51	16.46	28.02	50.73	<0.001
Division	38.44	15.88	6.04	10.67	32.40	<0.001
Overall	57.38	20.12	16.33	11.84	41.05	<0.001

Note. Sangihe, $n = 32$; Jayawijaya, $n = 48$. The reported *p*-values indicate statistically significant differences between regions for all domains. The overall comparison yielded $t(78) = 10.23$, $p < 0.001$, with Cohen's $d = 2.49$.

The domain-specific results revealed that the largest baseline differences occurred in addition and subtraction, with gaps of 54.27 and 50.73 points, respectively. Division had the lowest mean score in both regions, particularly in Jayawijaya, where the mean was only 6.04, compared with 38.44 in Sangihe. These findings indicate that the disparity was not confined to

one arithmetic operation but extended across all five domains, with the magnitude varying by competency area.

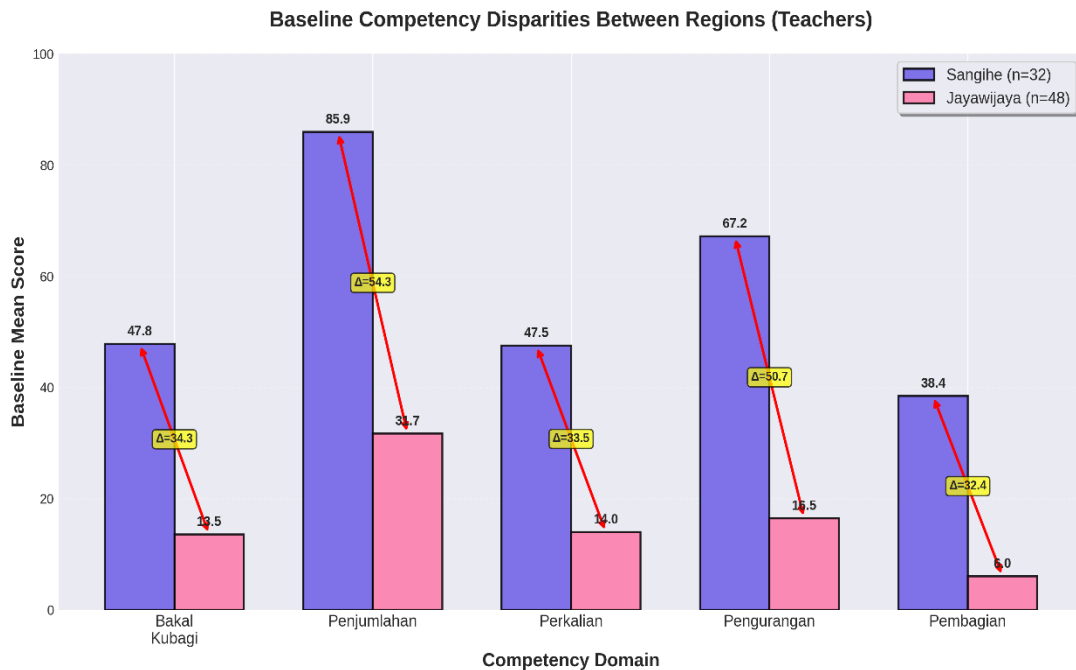


Figure 1. Baseline Competency Differences Between Sangihe and Jayawijaya

Figure 1 presents the baseline differences across the five arithmetic competency domains and the overall score. The visualization highlights the consistently higher mean scores among Sangihe teachers and the particularly wide gaps in addition and subtraction. Together, the table and figure establish the initial conditions against which subsequent training outcomes can be interpreted, while avoiding assumptions that geographical location alone explains the observed differences.

Post-Intervention Performance and Changes in Regional Disparities

Post-intervention assessments were used to examine changes in teachers' arithmetic knowledge following the intensive GASING training. Both regions recorded higher mean scores after the intervention, although their final performance levels remained different. Sangihe teachers achieved an overall mean of 98.81 (SD = 1.23), while Jayawijaya teachers reached 82.63 (SD = 9.45). The difference between the regional means decreased from 41.05 points at baseline to 16.18 points after training, representing a descriptive reduction of approximately 60.6% in the initial gap.

Table 2. Post-Intervention Performance and Learning Gains by Domain and Region

Competency Domain	Sangihe Post-test	Jayawijaya Post-test	Sangihe Gain	Jayawijaya Gain	Sangihe Improvement (%)	Jayawijaya Improvement (%)	Sangihe d	Jayawijaya d
Bakal Kubagi	99.38	78.33	51.56	64.79	107.9	478.5	7.37	2.93
Addition	99.38	86.46	13.44	54.79	15.7	173.0	1.20	1.62
Multiplication	97.19	83.54	49.69	69.58	104.6	498.4	4.80	3.43
Subtraction	99.69	86.88	32.50	70.42	48.4	427.8	2.77	2.64

Competency Domain	Sangihe Post-test	Jayawijaya Post-test	Sangihe Gain	Jayawijaya Gain	Sangihe Improvement (%)	Jayawijaya Improvement (%)	Sangihe d	Jayawijaya d
Division	98.44	77.92	60.00	71.88	156.3	1,190.0	5.08	3.76
Overall	98.81	82.63	41.44	66.29	86.6	553.6	4.24	2.88

Note. Gain = post-test mean minus pretest mean. Percentage improvement = gain divided by pretest mean, multiplied by 100. Cohen's d values are reproduced from the supplied results and should be interpreted after verifying the calculation method used for the pretest–posttest effect sizes.

The post-intervention results indicate that Sangihe teachers attained mean scores close to the upper limit of the assessment scale across all five domains. Jayawijaya teachers also demonstrated substantial improvement, with post-test means ranging from 77.92 in division to 86.88 in subtraction. Despite these improvements, the remaining overall difference of 16.18 points indicates that the two groups did not reach identical performance levels by the end of the training period.

Pre-Post Test Comparison: Teachers Across Regions

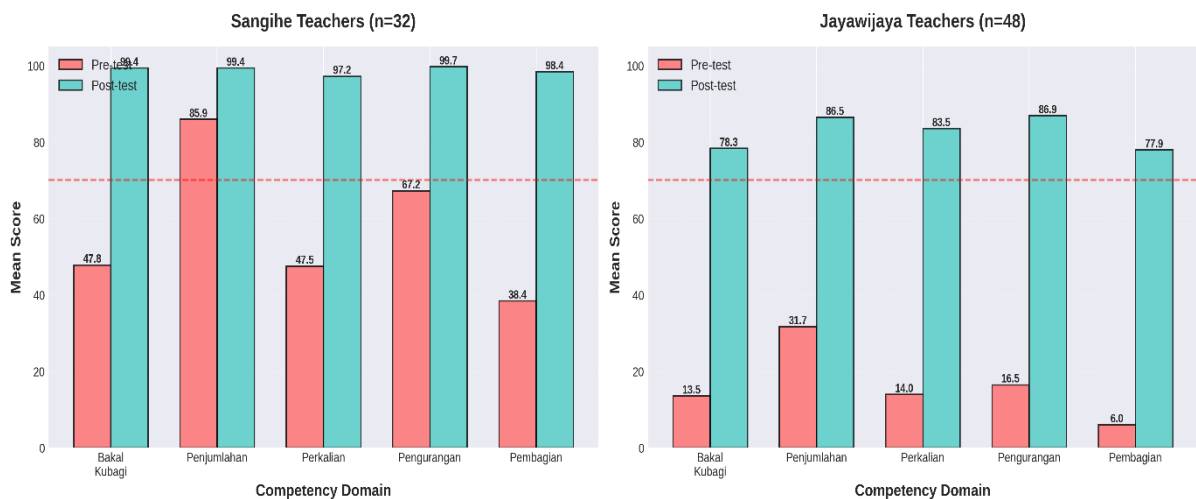


Figure 2. Pretest–Post-test Comparison Across Regions and Competency Domains

Figure 2 compares the mean scores before and after training in each region and arithmetic domain. The Sangihe results show relatively high initial scores followed by further improvement toward the upper end of the scale, whereas the Jayawijaya results show larger increases from substantially lower starting points. The figure therefore illustrates two distinct improvement patterns: consolidation of already stronger performance in Sangihe and more pronounced knowledge development from a lower baseline in Jayawijaya.

Absolute and Relative Learning Gains

To examine whether the magnitude of improvement differed between regions, absolute gains were calculated by subtracting pretest scores from post-test scores. Jayawijaya teachers recorded a mean gain of 66.29 points (SD = 12.34), exceeding the mean gain of 41.44 points (SD = 20.45) among Sangihe teachers. The reported independent-samples comparison indicated a statistically significant difference in gains, $t(78) = -6.12$, $p < 0.001$, with a reported Cohen's d of -1.50 . The negative sign reflects the order of subtraction in the comparison; the substantive result is that the mean gain was greater in Jayawijaya.



Figure 3. Absolute Learning Gains by Competency Domain and Region

Figure 3 displays the absolute gains recorded in each competency domain for both regions. Jayawijaya teachers achieved greater gains in all five domains, with the largest regional differences in addition and subtraction. Specifically, the gain advantage for Jayawijaya was 41.35 points in addition and 37.92 points in subtraction, while the differences in Bakal Kubagi, multiplication, and division were 13.23, 19.89, and 11.88 points, respectively. This consistent pattern indicates that teachers with lower initial scores experienced greater absolute improvements during the training period.

Relative improvement provides a complementary perspective by expressing the gain as a percentage of the baseline score. The reported average relative improvement was 553.6% in Jayawijaya and 86.6% in Sangihe, although these percentages should not be interpreted as directly comparable measures of final proficiency. The largest relative increase occurred in division among Jayawijaya teachers, whose mean score rose from 6.04 to 77.92, corresponding to an increase of approximately 1,190%. This result illustrates how a substantial absolute gain can translate into an exceptionally large percentage when the initial score is close to zero.

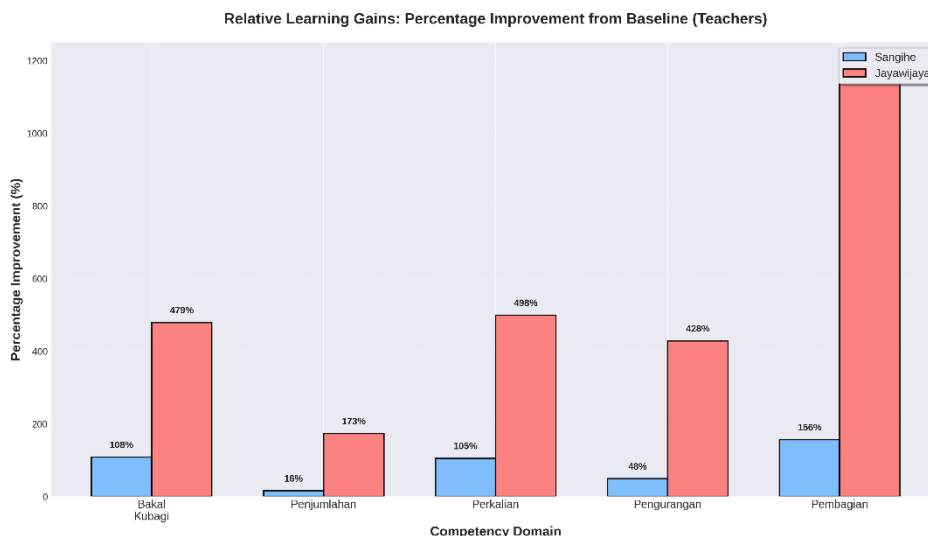


Figure 4. Relative Learning Gains as a Percentage of Baseline Scores

Figure 4 compares the percentage improvements across the five competency domains and highlights the especially large relative increases among Jayawijaya teachers. Division shows the most pronounced percentage change because the baseline score was very low, while addition shows a smaller relative increase in Sangihe, where initial performance was already comparatively high. These patterns demonstrate the importance of interpreting relative gains alongside baseline and post-test scores, as percentage-based measures can magnify changes when starting values are small.

Effect Sizes Across Competency Domains

Effect sizes were examined to describe the magnitude of the observed pretest–post-test differences across regions and competency domains. Based on the supplied calculations, the reported Cohen’s *d* values ranged from 1.20 to 7.37 for Sangihe and from 1.62 to 3.76 for Jayawijaya. The largest reported value for Sangihe occurred in Bakal Kubagi ($d = 7.37$), whereas the largest for Jayawijaya occurred in division ($d = 3.76$). All reported values exceed the conventional benchmark of 0.80 for a large effect, although the unusually high magnitudes warrant verification of the effect-size formula and the standard deviations used.

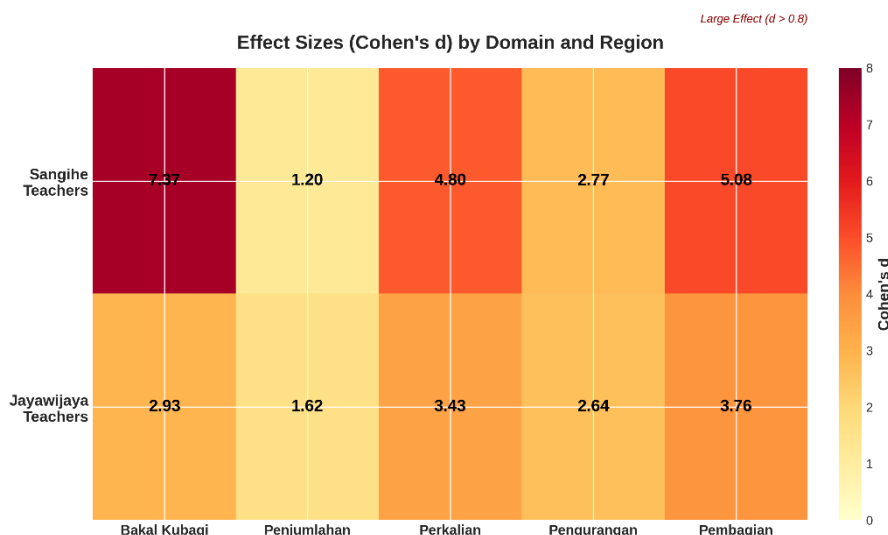


Figure 5. Effect Sizes (Cohen’s *d*) by Competency Domain and Region

Figure 5 presents the reported effect sizes for the five competency domains in both regions. The visualization shows large reported pretest–post-test differences throughout the assessment, with the highest value in Sangihe occurring in Bakal Kubagi and the highest value in Jayawijaya occurring in division. Addition has the smallest reported effect size in both regions, consistent with its comparatively smaller gain in Sangihe and its higher initial mean score. These results suggest that the magnitude of observed improvement varied by domain and regional starting point, rather than following a uniform pattern across all arithmetic competencies.

The combined findings from the baseline, post-intervention, and learning-gain analyses show that the training period was associated with substantial improvements in teachers’ arithmetic knowledge in both regions. Jayawijaya teachers recorded greater absolute and relative gains, whereas Sangihe teachers attained higher final scores across all five domains. Nevertheless, because the study did not include a control group or randomized assignment, these changes should be interpreted as improvements observed following the GASING intervention rather than definitive evidence that the intervention alone caused the gains. The

findings also indicate that immediate post-test performance does not establish whether the knowledge acquired was retained or translated into sustained classroom practice.

Discussion

Baseline Disparities in Teachers' Arithmetic Knowledge

The findings reveal substantial differences in arithmetic knowledge between teachers in the Sangihe Islands and the Jayawijaya Highlands before the GASING training. The overall mean score was 57.38 in Sangihe and 16.33 in Jayawijaya, with statistically significant differences across all five competency domains. The largest gaps occurred in addition (54.27 points) and subtraction (50.73 points), while division had the lowest baseline score in Jayawijaya (6.04). These results establish that the participating teachers entered the program with markedly different levels of mathematical knowledge, making baseline competence an essential consideration when evaluating professional development outcomes.

The findings are consistent with research emphasizing that mathematical content knowledge and pedagogical content knowledge are distinct but interconnected dimensions of teaching expertise (Copur-Gencturk & Tolar, 2022). Teachers require more than the ability to obtain correct answers; they also need to understand mathematical relationships and explain procedures in ways that support students' conceptual development. Research on mathematics teachers' pedagogical content knowledge further highlights the importance of subject-specific knowledge for organizing effective instruction (Barut et al., 2021; Ekawati et al., 2022; Kurniadi et al., 2022). From this perspective, the low baseline scores in Jayawijaya indicate a need for targeted professional learning that strengthens foundational arithmetic knowledge before teachers are expected to develop more advanced instructional strategies.

However, the regional differences should not be interpreted as direct evidence that geographical isolation caused lower teacher competence. The study did not measure the quality of participants' initial teacher preparation, access to previous professional development, school resources, or other contextual factors that might explain the disparity. The findings therefore establish an observed regional difference among the participating teachers rather than a causal relationship between location and competence. This distinction is important for developing equitable interventions that respond to demonstrated learning needs without attributing systemic challenges to individual teachers.

Improvements Following GASING-Based Professional Development

The second major finding is that both groups demonstrated substantial increases in arithmetic knowledge following the intensive training. The overall mean score in Sangihe increased from 57.38 to 98.81, while the Jayawijaya mean increased from 16.33 to 82.63. These changes indicate that the training period was associated with improvement in both contexts, despite differences in participants' starting points. The results provide encouraging evidence that intensive, subject-focused professional learning can support teachers in strengthening arithmetic knowledge in geographically diverse settings.

This pattern is consistent with research emphasizing the value of structured and integrated professional development for mathematics teachers. Rosli and Aliwee (2021) identify professional development as an important area of mathematics education research, while Johari et al. (2022) examine the contribution of integrated professional development to teachers' learning. More recent evidence also indicates that mathematics-focused professional development can improve educational outcomes, although effects vary across programs and contexts (Park et al., 2025). The present findings extend this discussion by documenting

teacher-level knowledge changes across five arithmetic domains in two geographically contrasting Indonesian regions.

Several features of the GASING program may have supported these improvements. The training combined concrete materials, visual representations, mathematical symbols, guided practice, feedback, peer teaching, and reflection. This sequence is consistent with the pedagogical logic of the concrete–pictorial–abstract approach, which supports the transition from concrete representations to visual models and symbolic reasoning (Azzumar & Juandi, 2023; Lutfi & Dasari, 2024). By engaging teachers in structured arithmetic activities rather than relying exclusively on verbal explanations, the program provided opportunities to practise calculations and examine mathematical relationships. Nevertheless, because the study did not isolate individual training components, the relative contribution of these features cannot be determined from the available data.

The findings also complement previous studies investigating GASING in elementary mathematics education. Research has examined its application to two-digit multiplication (Maulida et al., 2024), addition (Ramadhanti et al., 2024), and multiplication skills among elementary school students (Yuliyanto et al., 2024). Other studies have investigated GASING in relation to numeracy development and arithmetic performance (Resky et al., 2025; Gesiradja et al., 2026; Yuana et al., 2026). Whereas these studies focus primarily on students' mathematics learning, the present study examines teachers' own arithmetic knowledge following professional development. This distinction is important because evidence of improved student performance does not automatically establish that teachers have strengthened their mathematical knowledge.

The reduction in the regional mean-score gap from 41.05 to 16.18 points further indicates descriptive convergence after training. The gap narrowed by approximately 60.6%, demonstrating that the lower-scoring group made greater progress during the intervention period. However, convergence should not be confused with complete equality of competence. Jayawijaya teachers still recorded lower post-test scores than their Sangihe counterparts, indicating that substantial initial differences remained relevant at the end of training. The findings therefore support continued professional learning rather than the assumption that a single intensive program can fully address longstanding differences in teachers' preparation.

Differences in Learning Gains Across Regions

A comparison of absolute learning gains showed that Jayawijaya teachers improved by an average of 66.29 points, compared with 41.44 points among Sangihe teachers. The reported statistical comparison indicated a significant difference between the regional gains, with $t(78) = -6.12$ and $p < 0.001$. This pattern suggests that the teachers who began with lower scores had greater room for improvement during the training period. Consequently, evaluating professional development solely through final scores would provide an incomplete picture of teacher learning across groups with different baseline competencies.

The differences in starting points are particularly important when interpreting the results in Sangihe. In addition, the baseline mean was already 85.94, leaving limited room for further improvement on a 100-point assessment scale. The post-test mean of 99.38 therefore represents a comparatively small absolute gain of 13.44 points, even though the final performance was very high. In contrast, Jayawijaya teachers increased their addition score from 31.67 to 86.46, yielding a gain of 54.79 points. This comparison illustrates how ceiling constraints can limit measurable gains among participants whose initial scores are already high.

The relative improvement figures reinforce this pattern but require careful interpretation. Jayawijaya recorded an average reported improvement of 553.6%, compared

with 86.6% in Sangihe. The most pronounced relative increase occurred in division in Jayawijaya, where the mean rose from 6.04 to 77.92. Although the reported increase of approximately 1,190% appears exceptionally large, it is partly a consequence of the very low baseline denominator. The absolute gain of 71.88 points and the post-test mean provide a more interpretable account of the magnitude of change than the percentage alone.

These findings suggest that both absolute and relative measures are useful when evaluating teacher professional development, provided that their limitations are acknowledged. Absolute gains indicate the number of points gained, while relative gains describe the change in relation to initial performance. Neither measure alone establishes the quality of teachers' subsequent classroom instruction or the durability of their learning. Future evaluations should therefore combine score changes with delayed assessments and observations of teaching practice to determine whether the gains persist and influence instruction.

Domain-Specific Learning Patterns and Effect Sizes

The analysis across five competency domains reveals that improvement was not uniform. Jayawijaya teachers recorded their largest absolute gain in division (71.88 points), followed by subtraction (70.42 points) and multiplication (69.58 points). Sangihe teachers also improved across all domains, but their gains varied considerably, ranging from 13.44 points in addition to 60.00 points in division. These differences demonstrate the importance of examining domain-specific outcomes rather than relying exclusively on overall scores.

The particularly large gain in division among Jayawijaya teachers is consistent with the need to strengthen foundational arithmetic knowledge where initial performance is weakest. GASING uses structured activities and progressively developed calculation strategies, while the concrete–pictorial–abstract approach provides a framework for connecting representations with symbolic procedures (Azzumar & Juandi, 2023; Lutfi & Dasari, 2024). Such instructional features offer a plausible explanation for why an intensive program addressing foundational arithmetic may be useful when participants have substantial gaps in their initial knowledge. However, the current study did not directly measure the learning mechanisms involved, so this explanation should be treated as an interpretation rather than a demonstrated causal pathway.

The reported effect sizes were large across all domains, ranging from 1.20 to 7.37 in Sangihe and from 1.62 to 3.76 in Jayawijaya. These estimates suggest substantial standardized differences between pretest and post-test performance according to the reported calculations. Nevertheless, the magnitudes, particularly values exceeding 5.00, require verification using the original data and a clearly specified effect-size formula. Near-ceiling post-test scores, low baseline scores, and the choice of standard deviation used in the calculation can affect the interpretation of standardized changes. The results should therefore not be compared directly with effect sizes from other professional development studies until the calculations and underlying outcome measures are confirmed.

The reported effect sizes also do not demonstrate that GASING is more effective than other professional development approaches. The study did not include a comparison group receiving an alternative intervention, and the two regional groups differed substantially at baseline. The defensible conclusion is that large pretest–post-test differences were observed following the training, not that the program has been shown to outperform other approaches. Future comparative studies should employ clearly specified effect-size calculations and appropriate control or comparison conditions to estimate the intervention's contribution more precisely.

Implications for Equitable and Context-Responsive Professional Development

The findings have practical implications for designing professional development in geographically isolated educational communities. First, training should be responsive to teachers' demonstrated knowledge needs rather than assuming that all participants require the same level of instruction in every arithmetic domain. The low initial scores in division and foundational concepts in Jayawijaya indicate that these areas warrant particular attention, while the smaller gain in addition among Sangihe teachers suggests that training for higher-baseline participants may need to place greater emphasis on consolidation and deeper mathematical reasoning. Diagnostic assessments can help identify these differences before training begins and support more appropriate instructional planning.

Second, the substantial improvements observed in both regions support the continued investigation of intensive, content-focused training that combines explanations with active practice. Research on mathematics teacher development emphasizes the importance of examining how professional learning contributes to changes in teacher knowledge and practice (Benedict et al., 2023; Ding et al., 2023). For GASING-based programs, this means that immediate post-tests should be complemented by follow-up assessments, mentoring, and classroom observations. These measures would help establish whether teachers retain the knowledge acquired during training and apply it effectively in their own classrooms.

Third, contextual adaptation should be maintained while ensuring that the mathematical learning objectives remain consistent. The use of locally relevant examples, such as agricultural calculations in Jayawijaya and fishing-related examples in Sangihe, may help connect arithmetic activities to teachers' familiar experiences. However, the present study did not separately evaluate the effects of these adaptations. Further research should investigate whether local examples improve participation, conceptual understanding, or the transfer of knowledge to classroom instruction, particularly in settings with linguistic and cultural diversity.

Finally, the remaining post-intervention gap indicates that short-term professional development should form part of a broader teacher-support system. Access to appropriate teaching materials, opportunities for collaborative learning, and continuing instructional guidance may help sustain the gains observed during intensive training. The current results do not establish the cost-effectiveness of a particular implementation model, but they identify a basis for further evaluation of how training, mentoring, and local capacity building can be combined. Such an approach would recognize immediate improvements while addressing the continuing support needed for more equitable mathematics instruction.

Limitations and Directions for Future Research

Several limitations should be considered when interpreting these findings. First, the quasi-experimental pretest–post-test design did not include a control group or random assignment. Although scores increased following the training, the design cannot establish that the intervention alone caused the changes. Future studies should incorporate comparison groups, preferably with randomized assignment where feasible, to strengthen causal inference. Second, the assessments were administered immediately before and after the training. Consequently, the results establish short-term changes in measured arithmetic knowledge but do not show whether these gains were retained over time or translated into classroom practice. Follow-up assessments and structured classroom observations are needed to examine knowledge retention, instructional implementation, and possible effects on student learning.

Third, the study involved 80 teachers from only two regions selected through convenience sampling. The findings therefore should not be generalized to all teachers in Sangihe, Jayawijaya, or other remote regions without further evidence. Replication across

additional locations and participant groups would help determine whether the observed patterns are consistent across different educational settings.

Fourth, the use of standardized tests developed by the GASING program developers may limit the independence of the outcome assessment. Although the instruments had previously been piloted and reported reliability coefficients of 0.82–0.89, independent assessment and transparent reporting of scoring procedures would strengthen confidence in the results. The unusually large reported effect sizes also require recalculation and verification using the original participant-level data.

Finally, the study did not include detailed process data on training fidelity, participant engagement, or the contribution of specific instructional components. It therefore remains unclear which elements of the program were most closely associated with the observed gains. Mixed-methods research incorporating interviews, observations, and delayed assessments could provide a more comprehensive explanation of how GASING-based professional development supports teacher learning across different contexts.

Overall, the findings indicate that intensive GASING-based professional development was followed by substantial improvements in teachers' measured arithmetic knowledge in both Sangihe and Jayawijaya. The larger gains among Jayawijaya teachers demonstrate the importance of considering initial competence when evaluating training outcomes, while the remaining regional difference highlights the need for continued support. Further research should establish the durability, instructional significance, and comparative effectiveness of these improvements before stronger conclusions about causal impact and long-term educational equity are drawn.

CONCLUSION

This study found substantial improvements in elementary teachers' arithmetic knowledge following intensive professional development using the GASING method in the Sangihe Islands and the Jayawijaya Highlands. The overall mean score increased from 57.38 to 98.81 in Sangihe and from 16.33 to 82.63 in Jayawijaya. Jayawijaya teachers achieved a greater absolute gain of 66.29 points, compared with 41.44 points in Sangihe, while the gap between regional mean scores decreased from 41.05 to 16.18 points. Improvements occurred across all five competency domains, particularly division among Jayawijaya teachers. These findings indicate that GASING-based professional development can support improvements in teachers' measured arithmetic knowledge, although differences in post-test performance remained between the two regions.

The findings highlight the importance of designing professional development that responds to teachers' initial competence and specific learning needs. Continued mentoring, follow-up assessments, and access to appropriate instructional materials are recommended to support the retention and application of acquired knowledge. However, because this study used a pretest–post-test design without a control group and assessed outcomes immediately after training, the results cannot establish definitive causal effects or long-term changes in classroom practice. Future research should incorporate comparison groups, longer follow-up periods, classroom observations, and additional geographical settings to assess the sustainability and broader educational implications of GASING-based professional development.

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