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Research Article

Bridging Learning Styles: How the GASING Method Fosters Inclusive Conceptual Understanding of Integers

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ABSTRACT

Purpose of the study: Despite growing evidence of the GASING (Easy, Fun, and Enjoyable) method's effectiveness, little is known about whether its benefits hold consistently across students with different learning styles. This study addressed that gap by analyzing improvements in junior high school students' conceptual understanding of integers through the GASING method, examined in relation to students' learning styles (visual, auditory, kinesthetic).

Methodology: A quantitative quasi-experimental nonequivalent control group design (2×3 factorial) was employed with 54 Grade VII students (27 per group) from a public junior high school in Humbang Hasundutan Regency. Data were collected using a conceptual understanding test (pretest-posttest) and a learning style questionnaire and analyzed with the Mann-Whitney U test, Kruskal-Wallis test, and two-way ANOVA ($\alpha = 0.05$).

Main Findings: Both groups had equivalent prior ability ($p = 0.944$). The experimental class achieved a significantly higher mean posttest score (90.60 vs. 80.06) and N-Gain (0.885 vs. 0.739; $p < 0.001$, large effect size $d = 1.19$). We found no significant differences by learning style or its interaction with teaching method ($p > 0.05$).

Novelty/Originality of this study: This study provides novel evidence that the GASING method is equally effective for visual, auditory, and kinesthetic learners, demonstrating its inclusive multisensory design and eliminating the need for differentiated instruction based on learning style in integer learning at the junior high school level. Practically, this means teachers can use a single, unified GASING lesson design in heterogeneous classrooms, reducing planning burden while still meeting diverse learners' needs.

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1. INTRODUCTION

Integers represent a fundamental topic in mathematics that serves as an important prerequisite for understanding more advanced topics such as algebra, linear equations and inequalities, and statistics [1], yet even experienced teachers can struggle to model integer operations correctly [2]. In Indonesia, this topic is introduced

at the Junior High School (SMP) level in Grade VII in accordance with the Merdeka Curriculum [3], whose mathematics content at this level closely parallels that of other national systems in its emphasis on numeracy and problem-solving [4], and whose implementation continues to shape how mathematics is taught in Indonesian classrooms [5]. However, many students still experience difficulties in understanding integer operations, particularly those involving negative numbers, due to instructional approaches that tend to be abstract, lack contextual relevance, and are insufficiently engaging.

Instruction that emphasizes procedural memorization without conceptual understanding risks generating misconceptions [6], namely errors in connecting new concepts with students' pre-existing knowledge [7]. Fuadiah, Suryadi, and Turmudi [8] also found that conceptual misunderstandings of negative numbers persist due to a gap between students' understanding and the actual scientific concept. Putri, Maison, and Huda [9] identified the cognitive structure of junior high school students' misconceptions regarding integer arithmetic operations, and Ainia and Amir [10] found that elementary school students still experience significant difficulties solving word problems involving integers due to weak conceptual understanding. More recently, Yanala, Isa, and Uke [11] documented persistent conceptual gaps in integer operations among junior high school students in Indonesia, and Maulida and Sutama [12] similarly found that subtraction of integers remains a frequent source of misconception at this level. Sipayung and Anzelina [13] further showed that students' problem-solving skills on integer material improve when instruction is grounded in realistic, contextual approaches, and Sercenia, Ibañez, and Pentang [14] found that junior high school students' conceptual understanding of integers is closely tied to their metacognitive awareness.

These issues align with the findings of the 2022 Programme for International Student Assessment (PISA), which showed that Indonesia's mathematics score declined by 13 points compared to 2018, with only 18.35% of students meeting the minimum competency standard [15]. This national-level evidence underscores the urgency of interventions that strengthen conceptual understanding rather than rote procedure, since Kilpatrick, Swafford, and Findell [16] affirm that conceptual understanding constitutes an integrated and functional mastery of mathematical ideas that enables students to organize knowledge coherently, making it easier to remember, apply, and reconstruct, a view echoed by Kholid, Imawati, Swastika, Maharani, and Pradana [17] in their study of Indonesian junior high school students' conceptual understanding in mathematical problem solving.

Skemp [18] similarly distinguished between relational and instrumental understanding, arguing that relational understanding, which involves knowing both what to do and why, leads to more durable and transferable knowledge. Sfard [19] further elaborated the dual nature of mathematical concepts as both processes and objects, underscoring the importance of building conceptual structures from the ground up. Carpenter and Lehrer [20] likewise argued that understanding in mathematics develops from activity and reflection, and Merrill [21] emphasized that effective instruction activates prior knowledge and demonstrates skills in real-world contexts before asking learners to apply them independently.

One innovative learning method developed to address this problem is the GASING method (Gampang, Asyik, dan Menyenangkan – Easy, Fun, and Enjoyable), developed by Yohanes Surya. Its instructional sequence progresses through three interconnected phases: an initial hands-on phase where students interact with tangible objects and physical tools to build intuitive understanding, a representational phase where concrete experiences are translated into formal mathematical notation, and a final internalization phase in which students perform calculations mentally without reliance on external aids [22]. This staged approach aligns with Bruner's [23] theory of representation, emphasizing enactive, iconic, and symbolic stages in building meaningful understanding. It also resonates with Kolb's [24] experiential learning cycle, which posits that concrete experience precedes abstract conceptualization, and with Van de Walle, Karp, and Bay-Williams [25], who advocate for the use of manipulatives in building procedural and conceptual fluency in early mathematics. Previous research has shown the GASING method to be effective in improving learning outcomes and mathematical conceptual understanding across various levels, including integer concepts at the elementary school level [26]–[29], multiplication arithmetic operations [30]–[34], integer addition ability [35], and general mathematics learning outcomes more broadly [36]. The systematic stages and their connection to learning styles are illustrated in Figure 1.

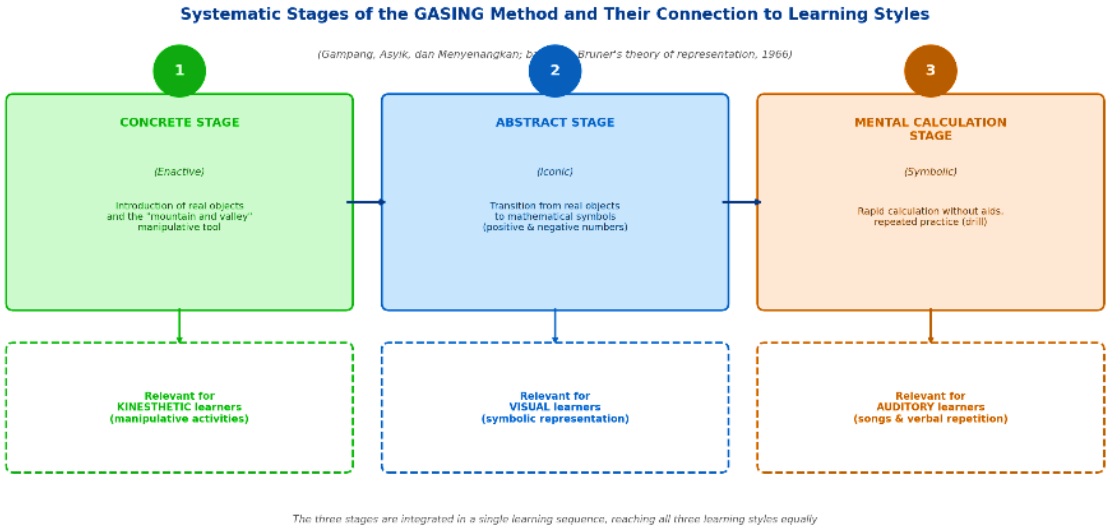


Figure 1. Systematic Stages of the GASING Method and Their Connection to Learning Styles

The effectiveness of a learning method is also closely related to students' learning styles, defined as characteristic patterns through which individual learners most effectively absorb, retain, and integrate new information, a construct that has been broadly operationalized into three modality-based categories: visual, auditory, and kinesthetic [37]–[39]. The GASING stages offer flexibility for all three: the hands-on phase engages kinesthetic learners through direct manipulation of objects, the representational phase benefits visual learners through spatial tools such as the "mountain and valley" model, and the mental internalization phase supports auditory learners through rhythmic verbal recitation and musical mnemonics. Fatonah and Nur [40] found kinesthetic to be the most dominant learning style among junior high school students, a pattern also reported by Supit, Melianti, Lasut, and Tumbel [41] in their study of learning style and achievement, and Yuniarti, Abidin, and Restu [42] similarly emphasize that instruction insensitive to visual, auditory, and kinesthetic differences risks leaving representational and conceptual gaps unaddressed.

While prior studies confirm that GASING improves learning outcomes in general [26]–[28], [30], [35] and that learning style shapes how students absorb instruction [40], no study to date has explicitly tested whether GASING's effectiveness on integer conceptual understanding is consistent across visual, auditory, and kinesthetic learners at the junior high school level, nor examined the interaction between teaching method and learning style. This gap matters because if GASING's benefits vary by learning style, teachers would need differentiated implementation; if not, a single unified design would suffice, a question this study directly resolves.

Based on this background, this study aims to: (1) describe the profile of students' learning styles; (2) analyze differences in mathematical conceptual understanding achievement and improvement between the GASING method and direct instruction; (3) analyze differences based on learning style following GASING implementation; and (4) analyze the interaction effect between teaching method and learning style on conceptual understanding on integer material. These aims are formalized into the following research questions: RQ1, What is the profile of students' learning styles in the sample? RQ2, Does the GASING method produce significantly higher conceptual understanding achievement and improvement than direct instruction? RQ3, Do students with different learning styles differ in conceptual understanding achievement and improvement after receiving the GASING method? RQ4, Is there a significant interaction effect between teaching method and learning style on conceptual understanding of integers?

2. RESEARCH METHOD

This study employed a quantitative approach with a quasi-experimental nonequivalent control group design [43], [44], with a 2×3 factorial design involving teaching method (GASING vs. direct instruction) and students' learning style (visual, auditory, kinesthetic). The study population consisted of all Grade VII students at a public junior high school in Humbang Hasundutan Regency during the 2025/2026 academic year. The sample was determined using an intact-class (cluster) sampling technique, in which two pre-existing classes were assigned as the experimental and control groups without randomizing individual students, consistent with the nonequivalent control group design in which naturally formed classes cannot be broken up for random assignment [43]. The sample comprised Class VII E as the experimental class (n = 27, GASING method) and

Class VII D as the control class (n = 27, direct instruction), for a total of 54 students. The study was conducted from September to November 2025.

The research instruments comprised three types. First, a learning style questionnaire using a four-point Likert scale, adapted from DePorter and Hernacki's (2000) learning-style indicators, as cited in [45], for the visual, auditory, and kinesthetic dimensions. Second, a mathematical conceptual understanding test of seven essay items on integers, developed by the researchers, covering three indicators: expressing concepts in one's own words, identifying examples and non-examples, and applying concepts in various situations (pretest-posttest; maximum 26 points, converted to 0–100 scale). Third, student activity observation sheets for triangulation. Data were collected through three stages: administration of the learning style questionnaire prior to treatment, a pretest before the intervention, and a posttest after eight meetings of instruction (four for each phase of the GASING sequence per topic), supplemented by observation during each session. All instruments were validated by the supervising lecturer through expert judgment and piloted before use; the seven-item conceptual understanding test showed acceptable internal consistency, with a Cronbach's alpha of 0.71 computed from the pretest administration across the full sample (n = 54).

Improvement was calculated using the normalized gain score (N-Gain) by Hake [46]: N-Gain = (posttest – pretest) / (maximum – pretest), with criteria: $g > 0.7$ (high), $0.3 \leq g \leq 0.7$ (medium), $g < 0.3$ (low). This formula has been widely applied in mathematics education research to measure learning effectiveness [47]. Prior to inferential analysis, Shapiro-Wilk normality [48] and Levene homogeneity tests [49] were conducted ($\alpha = 0.05$). Since normality was not satisfied, the Mann-Whitney U test was used for two-group comparisons, consistent with recommended practice for choosing between parametric and non-parametric tests under non-normality [50], and two-way ANOVA for interaction analysis [51]. The research design flow is illustrated in Figure 2.

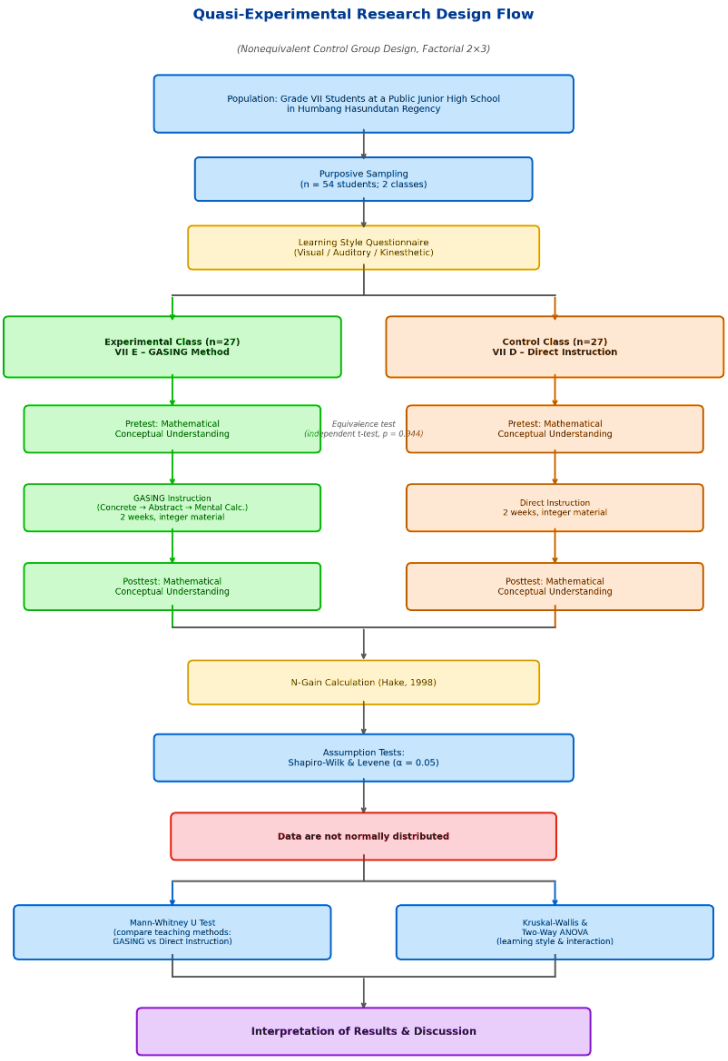


Figure 2. Research Design Flow: Quasi-Experimental Nonequivalent Control Group Design, 2×3 Factorial

3. RESULTS AND DISCUSSION

3.1 Learning Style Profile of Students

The results of student grouping based on the learning style questionnaire showed that all three learning style categories were relatively evenly distributed across both groups, with kinesthetic slightly more dominant. The distribution is presented in Table 1.

Table 1. Distribution of Students' Learning Styles in the Control and Experimental Classes

Learning Style	Control Class (F)	Control Class (%)	Exp. Class (f)	Exp. Class (%)
Visual	8	29.6	9	33.3
Auditory	8	29.6	8	29.6
Kinesthetic	11	40.7	10	37.0
Total	27	100	27	100

Source: Results of learning style questionnaire processing (2025)

In the control class, kinesthetic was held by 11 students (40.7%), followed by visual and auditory with 8 students each (29.6%). A similar pattern appeared in the experimental class: kinesthetic 10 (37.0%), visual 9 (33.3%), auditory 8 (29.6%). The similar proportions indicate that both groups possessed equivalent learning style characteristics prior to treatment, so post-treatment differences can be attributed to the teaching method rather than learning style composition. Figure 3 displays the distribution.

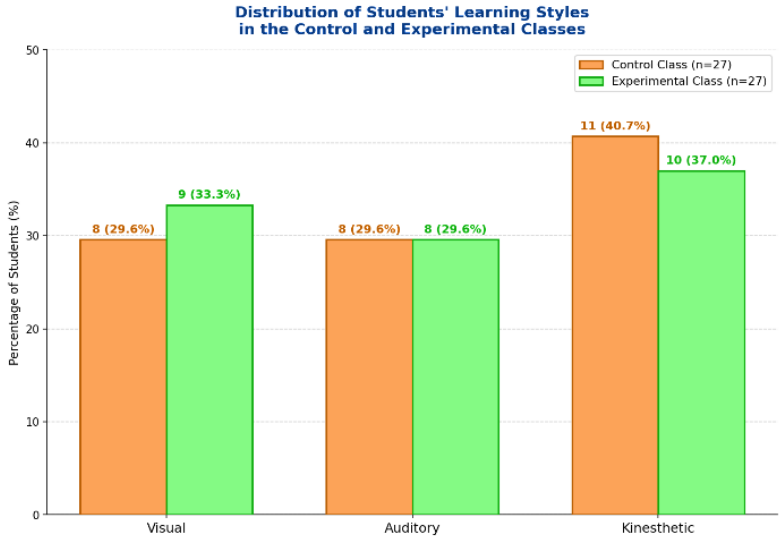


Figure 3. Distribution of Students' Learning Styles in the Control and Experimental Classes

3.2. Descriptive Statistics of Pretest, Posttest, and N-Gain

Before treatment, a pretest confirmed equivalent prior ability: no significant difference between control class ($M = 29.77$; $SD = 16.09$) and experimental class ($M = 29.49$; $SD = 13.53$), $t(52) = -0.070$, $p = 0.944$. Descriptive statistics are presented in Table 2.

Table 2. Descriptive Statistics of Pretest, Posttest, and N-Gain Scores

Group	Data	Mean	SD	Min	Max
Control (Direct) n = 27	Pretest	29.77	16.09	11.54	61.54
	Posttest	80.06	11.14	65.38	100.00
	N-Gain	0.739	0.127	0.591	1.000
Exp. (GASING) n = 27	Pretest	29.49	13.53	11.54	53.85
	Posttest	90.60	10.19	73.08	100.00
	N-Gain	0.885	0.119	0.667	1.000

Source: Results of pretest-posttest data processing (2025)

Table 2 shows the experimental class (90.60) outperformed the control class (80.06) in mean posttest score despite nearly identical pretests. The experimental class mean N-Gain (0.885; high category) exceeded the control class (0.739; medium-to-high boundary). Individually, 92.6% of experimental class students achieved high N-Gain vs. 48.1% in the control class. Figure 4 presents the comparison.

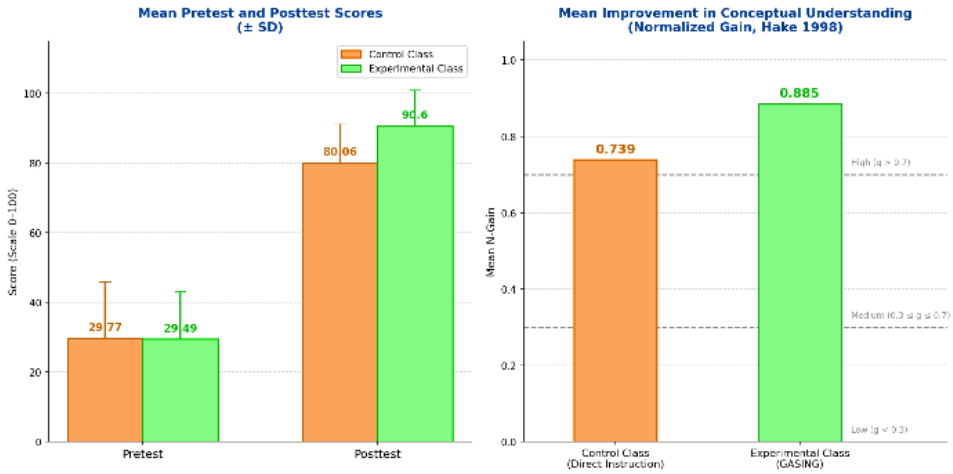


Figure 4. Comparison of Mean Pretest-Posttest Scores and N-Gain for the Control and Experimental Classes

3.3. Assumption Tests for Analysis

Prior to hypothesis testing, Shapiro-Wilk normality and Levene homogeneity tests were conducted ($\alpha = 0.05$). Results are presented in Table 3.

Table 3. Results of Shapiro-Wilk Normality and Levene Homogeneity Tests

Data	Group	Shapiro-Wilk (p)	Levene (p)	Remark
Pretest	Control	0.006	0.419	Not normal; homogeneous
	Experimental	0.032		Not normal
Posttest	Control	0.025	0.837	Not normal; homogeneous
	Experimental	0.0002		Not normal
N-Gain	Control	0.002	0.816	Not normal; homogeneous
	Experimental	0.0004		Not normal

Source: Results of data processing (2025)

All Shapiro-Wilk p-values < 0.05 indicate non-normal distribution. Levene test results ($p > 0.05$) confirmed homogeneity. Given non-normality, the Mann-Whitney U test was used for two-group comparisons. Drezner and Turel [52] confirmed that the Mann-Whitney U test remains robust and appropriate for non-normal distributions of this type.

3.4. Differences Between GASING Method and Direct Instruction

The Mann-Whitney U test was conducted to determine whether the GASING method outperformed direct instruction in achievement and improvement of conceptual understanding. Results are shown in Table 4.

Table 4. Results of the Mann-Whitney U Test on Posttest Scores and N-Gain

Data	U	p (one-tailed)	Decision	Effect size (d)
Posttest (achievement)	554.0	0.0005	H_0 rejected	0.99 (large)
N-Gain (improvement)	590.5	< 0.001	H_0 rejected	1.19 (large)

Source: Results of data processing (2025)

Results show $p = 0.0005$ for posttest and $p < 0.001$ for N-Gain (both < 0.05), so H_0 is rejected: students in the GASING class achieved significantly better conceptual understanding. Cohen's d [53] = 0.99 (posttest)

and 1.19 (N-Gain) indicate large effect sizes; following current guidance on interpreting effect sizes in education and mathematics education specifically [54], [55], such magnitudes are substantially above the benchmarks typical of classroom interventions, confirming both statistical and practical significance.

3.5. Differences Based on Learning Style

The Kruskal-Wallis test was used to determine whether learning style produced differences in outcomes following the GASING method. Results are in Tables 5 and 6.

Table 5. Results of the Kruskal-Wallis Test Based on Learning Style

Data	H	df	P	Decision
Posttest (achievement)	0.728	2	0.695	H_0 accepted
N-Gain (improvement)	0.493	2	0.782	H_0 accepted

Source: Results of data processing (2025)

Table 6. Mean Posttest and N-Gain Based on Learning Style and Group

Learning Style	Posttest Control	Posttest Exp.	N-Gain Control	N-Gain Exp.	n (C/E)
Visual	75.96	89.74	0.707	0.880	8/9
Auditory	79.81	92.31	0.721	0.902	8/8
Kinesthetic	83.22	90.00	0.774	0.876	11/10

Note: C = Control; E = Experimental. Source: Results of data processing (2025)

With $p = 0.695$ (posttest) and $p = 0.782$ (N-Gain), both exceeding 0.05, H_0 is accepted: no significant differences based on learning style after the GASING method. Table 6 confirms consistently high posttest means across all three categories: visual (89.74), auditory (92.31), kinesthetic (90.00); and equivalent N-Gain values (all in the high category). Figure 5 visualizes these patterns.

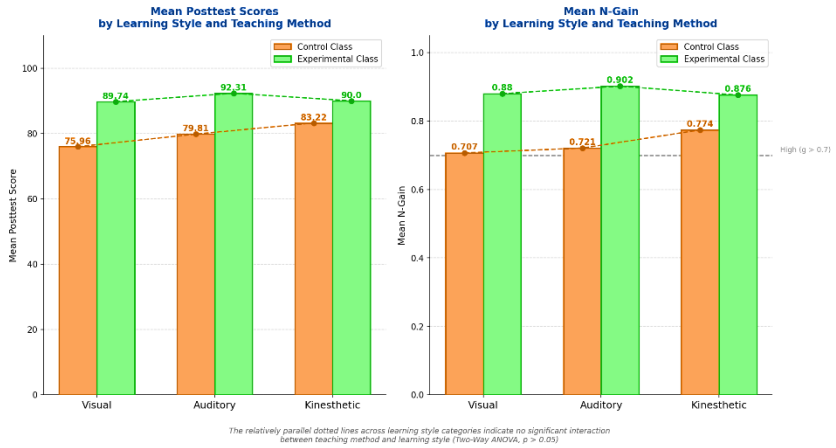


Figure 5. Mean Posttest and N-Gain Based on Learning Style and Teaching Method (Pattern with No Significant Interaction)

3.6. Interaction Effect Between Teaching Method and Learning Style

Two-Way ANOVA (2×3 factorial) was conducted to test interaction effects on posttest scores and N-Gain. Results are presented in Tables 7 and 8.

Table 7. Results of Two-Way ANOVA for Posttest Scores (Achievement)

Source of Variance	SS	df	MS	F	p
Teaching Method (A)	1500.05	1	1500.05	12.74	0.001
Learning Style (B)	107.77	2	53.88	0.46	0.635
Interaction (A×B)	170.42	2	85.21	0.72	0.490
Error	5650.28	48	117.71	-	-
Total	7428.53	53	-	-	-

Source: Results of data processing (2025)

Table 8. Results of Two-Way ANOVA for N-Gain (Improvement)

Source of Variance	SS	df	MS	F	p
Teaching Method (A)	0.289	1	0.289	18.17	< 0.001
Learning Style (B)	0.006	2	0.003	0.17	0.840
Interaction (A×B)	0.022	2	0.011	0.71	0.498
Error	0.763	48	0.016	-	-
Total	1.080	53	-	-	-

Source: Results of data processing (2025)

Teaching method had a significant main effect on both posttest ($F(1,48) = 12.74$; $p = 0.001$) and N-Gain ($F(1,48) = 18.17$; $p < 0.001$). Learning style did not produce a significant main effect ($p > 0.05$), and the interaction between teaching method and learning style was not significant for either outcome ($p > 0.05$). Interpretation of effect magnitudes followed guidelines by Marsh, Hau, and Wen [56], who recommend interpreting statistical effects in the context of specific study conditions. The absence of significant interaction confirms that the GASING method's advantage is consistent across all three learning style categories.

The findings indicate that the GASING method is significantly more effective than direct instruction in improving junior high school students' mathematical conceptual understanding of integer material, with large effect sizes. This reinforces prior research on GASING's effectiveness [26], [27], [57], [58] and mirrors the large gains reported for other structured, multi-phase approaches to building conceptual and procedural understanding in mathematics [59]. This superiority can theoretically be explained through the three-phase hands-on–representational–internalization sequence, aligned with Bruner's [23] enactive, iconic, and symbolic stages and Vygotsky's [60] zone of proximal development, which emphasizes the role of mediated learning in bridging students' existing knowledge and new concepts. This sequence parallels the concrete-representational-abstract (CRA) approach, whose effectiveness for building mathematical understanding has been confirmed in a recent meta-analysis [61] and in classroom applications for topics as abstract as algebra [62]. The "mountain and valley" manipulative in the hands-on phase helps students build meaning for positive and negative numbers before transitioning to mathematical symbols, minimizing misconceptions [8], [63], a function similar to that of the number-line models used in other integer instruction [64]. Koedinger and Alibali [65] also found that integrating conceptual and procedural instruction leads to deeper and more transferable mathematical knowledge, and Rittle-Johnson, Fyfe, and Loehr [66] similarly demonstrated that the way conceptual and procedural content is sequenced within a single lesson shapes how well both types of knowledge are retained. Silver [67] further argued that rich mathematical learning environments that emphasize problem solving foster greater conceptual growth than procedural drill alone.

The mean N-Gain of 0.885, with 92.6% of students in the high category, indicates consistent individual impact. This aligns with the GASING critical point principle [68] and Thorndike's Law of Exercise [69], which strengthens stimulus-response connections through repeated practice, contributing to longer-lasting conceptual understanding [16]. Santrock [70] similarly noted that spaced and repeated practice is fundamental to consolidating knowledge in long-term memory.

The absence of significant differences based on learning style demonstrates the GASING method's inclusive design, consistent with Jonassen and Grabowski [71], who noted that individual differences in learning style do not necessarily produce differential learning outcomes when instructional conditions provide sufficient variety and scaffolding. This is consistent with Pashler et al. [72] and Rogowsky, Calhoun, and Tallal [73], [74],

who found across two empirical studies that matching instruction to a learner's preferred style does not improve outcomes, implying that well-designed multimodal approaches benefit learners regardless of their dominant learning style preference, consistent with the broader pattern identified by Hariri, Mahmudah, Wibawa, and Kania [75] in their systematic review of learning styles and mathematics achievement. The GASING method's three-phase architecture inherently serves all modalities simultaneously: kinesthetic learners are engaged through the hands-on phase, visual learners through the representational phase, and auditory learners through the mental internalization phase. The absence of significant interaction confirms this inclusivity: teachers need not design separate variations for different learning styles when implementing GASING [76]–[78].

Taken together, these findings can be generalized, with appropriate caution, to junior high school classrooms with a comparable heterogeneous mix of visual, auditory, and kinesthetic learners studying integer material under conditions similar to those of this study. The novelty of this study lies in demonstrating empirically, through a 2×3 factorial design, that GASING's advantage over direct instruction is not conditional on learning style, a question earlier GASING studies [26], [27], [35] did not test. Practically, this finding relieves teachers of the burden of designing separate, style-specific variations of the same lesson: a single well-sequenced hands-on–representational–internalization design can be implemented for an entire class regardless of its learning-style composition, making GASING a time-efficient option for schools with limited resources for differentiated instruction. This also has curricular implications, suggesting that teacher-training programs and lesson-planning guidelines for integer material could adopt GASING as a default rather than a supplementary strategy. Limitations include: (1) single-school study with a small sample (54 students); (2) intervention limited to a single semester (September–November 2025); and (3) quasi-experimental design without full randomization. Future research should expand the sample across multiple schools, extend the intervention duration, and measure long-term retention of conceptual understanding.

4. CONCLUSION

This study set out to answer four research questions concerning students' learning style profile, the comparative effectiveness of the GASING method, and its relationship with learning style in developing conceptual understanding of integers. The findings show that learning styles were relatively evenly distributed with a kinesthetic tendency, and that the GASING method produced significantly greater achievement and improvement in conceptual understanding than direct instruction (mean posttest 90.60 vs. 80.06; mean N-Gain 0.885 vs. 0.739; large effect sizes), an advantage that held consistently across visual, auditory, and kinesthetic learners, with no significant interaction between teaching method and learning style. Theoretically, this study contributes to the literature by showing that the structure of a multi-phase instructional method, rather than a match to individual learning-style preference, can be the primary driver of conceptual understanding gains, lending empirical support to the view that well-designed multimodal instruction can render learning-style differentiation unnecessary. Practically, junior high school mathematics teachers can implement GASING on integer material as a single, inclusive design without developing separate variations per learning style, since its hands-on–representational–internalization structure inherently addresses all three modalities. For policy, these findings suggest that curriculum developers and teacher-training programs could position GASING as a recommended default strategy for integer instruction, reducing the resource burden on schools that currently lack capacity for differentiated instruction. Future research should extend this design to multiple schools with varied characteristics and examine long-term retention of the conceptual gains reported here.

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AUTHOR CONTRIBUTIONS

Conceptualization, T.S. and S.F.; Methodology, T.S. and J.A.D.; Formal Analysis, T.S.; Investigation, T.S.; Data Curation, T.S.; Writing – Original Draft Preparation, T.S.; Writing – Review & Editing, S.F. and J.A.D.; Supervision, S.F. and J.A.D.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects and their parents/guardians. All participants voluntarily agreed to participate and signed written informed consent forms. All images in this article have been authorized and are the property of the authors.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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