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Effects Of the Sign Dominance and Distance (SDD) Technique on Students' Performance in Integer Operation

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Abstract

This study investigated the effectiveness of the Sign Dominance and Distance (SDD) Technique in improving Grade 7 students' performance in integer operations, particularly addition and subtraction of integers, at Calamba National Comprehensive High School during the School Year 2025–2026. Anchored on Constructivist Theory, the study addressed the persistent conceptual difficulties learners experience in understanding negative numbers and abstract integer operations. A quasi-experimental non-equivalent control group pretest-posttest design was employed involving 72 Grade 7 students divided into experimental and control groups. The experimental group was taught using the SDD Technique, while the control group received Traditional Instruction. Data were gathered using a researcher-constructed 30-item Cognitive Performance Test validated by mathematics experts and tested for reliability using the Kuder-Richardson Formula 20 (KR-20). Mean, standard deviation, independent sample t-test, and Cohen's d were utilized in analyzing the data. Findings revealed that both groups initially demonstrated low proficiency in integer operations, particularly in subtraction. After the intervention, both groups improved; however, the experimental group achieved significantly higher posttest performance and demonstrated greater internal growth compared to the control group. The SDD Technique was particularly effective in improving addition of integers and enhancing conceptual understanding through visual and relational reasoning. Although subtraction remained challenging, the experimental group still demonstrated substantial improvement. The study concluded that the SDD Technique is a more effective instructional strategy than traditional rule-based methods in improving procedural fluency and conceptual understanding in integer operations. The findings support the integration of conceptually grounded and visually supported instructional approaches in mathematics education. The study aligns with SDG 4 – Quality Education by promoting effective and inclusive mathematics instruction and supports SDG 9 – Industry, Innovation and Infrastructure through the development of innovative teaching strategies. The study also contributes to educational and institutional sustainability by strengthening mathematical competence, improving instructional practices, and supporting evidence-based curriculum development.

Keywords: Addition of Integers, Cognitive Performance, Constructivist Theory, Integer Operations, Mathematics Education, Sign Dominance and Distance Technique, Subtraction of Integers

1. Introduction

Integer operations remain one of the most challenging competencies in middle school mathematics because students must transition from concrete natural number operations to the abstract and directional nature of integers. Difficulties often arise when learners encounter counterintuitive rules involving negative numbers, resulting in persistent misconceptions, computational errors, and weak algebraic foundations. Traditional approaches commonly rely on rote procedures that emphasize memorization rather than conceptual understanding, limiting students' ability to relate integer operations to meaningful mathematical representations. In response to this challenge, the present study examines the effectiveness of the Sign Dominance and Distance (SDD) Technique in improving Grade 7 students' performance in integer operations at Calamba National Comprehensive High School during the School Year 2025–2026.

1.1 Background of the Study

Mastery of integers is considered a fundamental prerequisite for learning algebra and higher mathematical concepts. However, many learners experience difficulty in understanding the operational behavior of negative numbers because integer rules often contradict prior arithmetic intuition. Students frequently struggle with understanding why adding a negative number decreases value or why subtracting a negative number increases value, causing confusion and cognitive overload during more advanced mathematical tasks. Traditional instruction in integer operations has commonly relied on rule-based procedures such as "keep-change-change," which prioritize procedural efficiency over conceptual depth. Such approaches often fail to connect symbolic operations with concrete representations like number lines and absolute value.

Consequently, students tend to memorize rules without understanding their underlying logic, which may negatively affect mathematical confidence and self-efficacy.

To address these instructional limitations, the study introduces the Sign Dominance and Distance (SDD) Technique as an alternative instructional strategy. The SDD Technique emphasizes relational and visual understanding by guiding learners through two processes: determining sign dominance through magnitude comparison and identifying numerical distance using number line representations. By integrating conceptual reasoning with procedural execution, the technique seeks to transform students' understanding of integer operations from fragmented memorization into coherent mathematical reasoning. Under the revised K–10 Mathematics Curriculum, learners are expected to demonstrate conceptual understanding, strategic problem-solving, and mathematical resilience. Despite these curricular goals, integer operations continue to be identified as a Least Mastered Skill (LMS), particularly in subtraction of integers. This difficulty is associated with weak understanding of spatial models and challenges in reconciling negative numbers with prior arithmetic knowledge (Vlassis, 2002). The SDD Technique is therefore proposed as an instructional intervention that bridges procedural fluency and conceptual understanding to support mathematical performance and critical thinking among Grade 7 learners.

1.2 Themes and Insights from Related Literature

Existing literature emphasizes that conceptual understanding is essential for successful learning in mathematics, particularly in integer operations. Studies highlight that students often rely heavily on memorized procedures without understanding the rationale behind operations involving negative numbers. This results in misconceptions, low retention, and difficulty applying concepts to higher-order mathematical tasks. Research further indicates that visual and relational instructional approaches improve learners' comprehension of abstract mathematical concepts. The use of number lines, spatial reasoning, and manipulative models helps students connect symbolic representations with concrete understanding. Such approaches reduce cognitive overload and support the development of mathematical reasoning and self-efficacy. Constructivist-oriented instructional strategies also suggest that learners achieve deeper understanding when they actively construct meaning from prior knowledge and experience. Approaches that encourage students to analyze relationships among numbers rather than memorize isolated rules contribute to stronger conceptual foundations and improved problem-solving performance.

1.3 Local, National, and Global Context

Locally, Grade 7 learners continue to demonstrate low mastery in integer operations, particularly in subtraction involving negative numbers. These difficulties are evident in classroom assessments where integer operations are consistently categorized as Least Mastered Skills. The struggle with integers affects learners' readiness for algebra and other advanced mathematical topics. Nationally, the Philippine K–10 Mathematics Curriculum promotes conceptual understanding, problem-solving competence, and mathematical literacy. However, gaps between curriculum goals and actual learner performance remain evident due to persistent reliance on rote teaching strategies and limited use of conceptual instructional approaches. Globally, mathematics education research emphasizes the importance of constructivist and learner-centered pedagogies in addressing misconceptions related to integers and abstract mathematical concepts. International studies advocate for instructional methods that integrate visual models, reasoning, and active learner engagement to improve mathematical understanding and performance.

1.4 Theoretical or Conceptual Basis

The study is anchored on the Constructivist Theory of Learning, which posits that learners actively construct knowledge through experience and reflection. Jean Piaget emphasized cognitive development and the formation of mental schemata, while Lev Vygotsky highlighted the role of social interaction and the Zone of Proximal Development in learning. Constructivism challenges rote memorization by promoting meaningful understanding and learner engagement. The SDD Technique aligns with constructivist principles by enabling learners to connect prior numerical understanding with the directional properties of integers. Through the concepts of sign dominance and distance, students actively analyze numerical relationships and use number lines as visual and spatial supports. This instructional approach encourages learners to construct meaning rather than rely solely on memorized procedures. The conceptual framework of the study examines the relationship between instructional method and mathematical performance. The independent variable consists of the instructional approaches, specifically the SDD Technique and Traditional Instruction, while the dependent variable is students' performance in addition and subtraction of integers. Pretest scores are utilized as covariates to account for initial differences in learner ability.

1.5 Research Gaps and Rationale

Despite curriculum reforms emphasizing conceptual understanding, many instructional practices in integer operations remain procedural and rule-oriented. Existing approaches often fail to address learners' misconceptions and cognitive difficulties associated with negative numbers. Although conceptual and visual strategies have been recommended in mathematics education, limited local studies have examined the effectiveness of structured interventions such as the Sign

Dominance and Distance (SDD) Technique among Grade 7 learners. The present study addresses this gap by investigating the effects of the SDD Technique on students' performance in integer operations using a quasi-experimental design. Specifically, the study compares the pretest and posttest performances of control and experimental groups to determine whether the SDD Technique significantly improves mathematical achievement in addition and subtraction of integers.

1.6 Alignment with Relevant Sustainable Development Goals (SDGs)

The study aligns primarily with SDG 4 – Quality Education because it seeks to improve mathematical understanding, conceptual learning, and instructional effectiveness among Grade 7 students. By introducing a conceptually grounded instructional technique, the study supports equitable and inclusive quality education through improved learning outcomes in mathematics. The research also supports SDG 8 – Decent Work and Economic Growth by strengthening foundational mathematical competencies necessary for future academic achievement, employability, and participation in a knowledge-based economy. Improved numeracy skills contribute to learners' long-term educational and professional development. Additionally, the study reflects SDG 9 – Industry, Innovation and Infrastructure through the development and evaluation of an innovative instructional strategy designed to enhance mathematics education and promote evidence-based teaching practices.

1.7 Importance of the Study to Multidisciplinary Sustainability

The study contributes to educational sustainability by promoting instructional practices that strengthen conceptual understanding, learner engagement, and long-term mathematical competence. Through the SDD Technique, students may develop greater procedural fluency, reduced mathematics anxiety, and improved self-efficacy, supporting sustainable academic growth. The study also contributes to socio-economic sustainability by improving learners' foundational mathematical skills, which are essential for academic progression and future workforce readiness. Strong numeracy competencies are critical for informed decision-making, technological adaptation, and participation in economic development. From an institutional and policy perspective, the findings may support curriculum planners and educators in designing evidence-based instructional interventions that align with national educational goals. The study further contributes to research sustainability by providing a methodological framework for future quasi-experimental studies examining cognitive and affective outcomes in mathematics education.

2. Material and methods

2.1 Research Design

The study employed a quasi-experimental research design utilizing the Non-equivalent Control Group Pretest/Posttest Design. This approach enabled the researcher to compare the performance of students exposed to the Sign Dominance and Distance (SDD) Technique and those taught using Traditional Instruction. Both groups were administered pretests and posttests to determine differences in performance before and after the intervention. The experimental group received instruction through the SDD Technique, while the control group was taught using conventional rule-based procedures in solving integer operations. To address the limitations of non-random assignment and intact grouping, Cohen's d was utilized to determine the practical magnitude of the intervention's effect. This statistical measure provided a standardized interpretation of the effectiveness of the SDD Technique beyond statistical significance alone. The SDD Technique focused on two major concepts: Sign Dominance and Distance. In determining sign dominance, students identified the integer with the greater absolute value, which dictated the sign of the answer. In determining distance, students calculated the numerical separation between integers using a manipulative number line. For example, in solving -10 + 4, students identified -10 as the dominant sign because it is farther from zero, then measured the distance between the two integers to obtain the answer of -6. The intervention emphasized guided practice, visual aids, structured exercises, and verbalization of solution steps to strengthen conceptual understanding. In contrast, the control group relied on traditional procedures such as subtracting magnitudes and assigning the sign of the larger number. The design of the study involved two intact groups that both underwent pretesting and posttesting, with only the experimental group receiving the SDD Technique intervention while the control group received Traditional Instruction. This arrangement enabled the researcher to determine the comparative effectiveness of the two instructional approaches in improving students' performance in integer operations.

2.2 Locale of the Study

The study was conducted at Calamba National Comprehensive High School (CNCHS), a public secondary school located in Calamba, Misamis Occidental, Region X, Philippines. The school was selected because of its large and diverse student population, which provided a heterogeneous sample suitable for the study. The administration and Mathematics Department of the school were supportive of educational research initiatives intended to improve student academic performance. Testing and intervention activities were conducted in the students' regular classrooms to maintain a familiar and controlled learning environment throughout the study.

2.3 Respondents of the Study

The respondents of the study were two intact Grade 7 classes from Calamba National Comprehensive High School enrolled during the School Year 2025–2026. No special education classes were included in the study. The total number of respondents was approximately 72 students, with 36 students assigned to the experimental group and 36 students assigned to the control group. The respondents were equally distributed between the two Grade 7 sections, with each section comprising 50 percent of the total sample population. The non-random assignment of respondents was statistically addressed through the use of pretest scores during data analysis.

2.4 Sample and Sampling Procedure

The study utilized non-random sampling through the selection of intact Grade 7 classes. One class served as the experimental group and the other served as the control group. Since respondents were not randomly assigned, pretest scores were used to account for initial differences between groups during statistical analysis. The quasi-experimental approach allowed the researcher to conduct the intervention within an actual classroom setting while preserving the natural composition of the classes. This procedure ensured practicality and feasibility in implementing the study within the school environment.

2.5 Research Instrument

The primary instrument used in the study was a researcher-constructed Cognitive Performance Test consisting of 30 items aligned with the Grade 7 Mathematics curriculum. To ensure content validity, a Table of Specifications (TOS) was prepared to align the test items with the learning competencies in integer operations. The instrument was divided into two sections consisting of 15 items for addition of integers and 15 items for subtraction of integers. This structure enabled separate analysis of student mastery in each operation. The instrument underwent expert validation by a Head Teacher, a Master Teacher, and a Grade 7 Mathematics teacher to ensure mathematical accuracy, clarity, and suitability for the respondents. A pilot test was conducted among 35 Grade 7 students who were not included in the actual study. Reliability testing using the Kuder-Richardson Formula 20 (KR-20) yielded a coefficient of 0.70, indicating acceptable internal consistency and reliability of the instrument for formal data collection. The scoring procedure focused solely on students' cognitive performance. Each correct answer was given one point. Scores ranging from 26 to 30 indicated mastery and demonstrated comprehensive understanding and high procedural fluency. Scores from 21 to 25 were interpreted as proficient, indicating strong working knowledge with minimal inconsistencies. Scores from 16 to 20 reflected developing performance, while scores from 0 to 15 indicated beginning performance and the need for intensive instructional support. Separate interpretations were provided for addition, subtraction, and overall performance to ensure a more detailed evaluation of student achievement.

2.6 Data Gathering Procedure

The data gathering process was conducted in three phases: preliminary, implementation, and post-implementation. During the preliminary phase, the researcher administered a pilot test to Grade 7 students who were not included in the actual sample to establish the validity and reliability of the instrument. Administrative approvals were secured from the Dean of the Graduate School of Jose Rizal Memorial State University, the Schools Division Superintendent of Misamis Occidental, the district supervisor, and the school principal. Parental consent and student assent were also obtained prior to participation to ensure ethical compliance. During the implementation phase, the intervention was conducted over one week. On the first day, both groups underwent orientation and a 50-minute pretest to establish baseline performance in integer operations. From the second to the fourth day, both groups studied identical lessons involving addition and subtraction of integers. The control group received Traditional Instruction using conventional procedures, worksheets, and chalkboard discussions. In contrast, the experimental group utilized the SDD Technique through manipulative number lines and guided conceptual activities focusing on sign dominance and distance. During the post-implementation phase, both groups completed a 50-minute posttest on the fifth day. The collected data were compiled, coded, and prepared for statistical analysis to determine the comparative effectiveness of the SDD Technique and Traditional Instruction in improving students' performance in integer operations.

2.7 Data Analysis Techniques

The collected data were analyzed using appropriate statistical tools. Mean and standard deviation were used to summarize the central tendency and variability of students' scores. The Independent Sample t-test was utilized to compare the pretest and posttest performances of the experimental and control groups. Cohen's d was employed to determine the effect size or practical magnitude of the intervention. While the t-test identified whether differences between groups were statistically significant, Cohen's d measured the extent of the intervention's impact in practical terms. Interpretation of effect sizes followed Sawilowsky's (2009) Refined Scale, which categorized effect sizes as very small, small, medium, large, very large, and huge.

2.8 Ethical Considerations

Prior to data collection, the researcher secured approval from the Research Ethics Committee (REC) and obtained administrative permission from relevant educational authorities. Since the respondents were minors, parental or guardian consent and student assent were secured before participation. Respondents were informed that participation was voluntary and that they could withdraw from the study at any time without academic consequences. To ensure fairness, students in the control group were granted access to the SDD Technique after the completion of the study. Measures were also implemented to minimize test anxiety, fatigue, and stress during the administration of assessments. The study was educational in nature and posed no physical risks to participants. Confidentiality and data privacy were strictly observed throughout the study. Student identities were coded to maintain anonymity, and individual scores were not disclosed to teachers or administrators during the conduct of the research. The study complied with the Data Privacy Act of 2012 (RA 10173). All collected data were securely stored in password-protected digital files and locked storage facilities for five years before permanent disposal.

3. Results and Discussion

3.1 Students' Performance in Integer Operations

3.1.1 Pretest Performance of the Control Group

The control group obtained an overall actual mean of 13.97 with a standard deviation of 5.54, interpreted as "Beginning." In addition of integers, the group achieved a mean score of 8.50 described as "Developing," while subtraction of integers yielded a mean of 5.47 interpreted as "Beginning." These scores were below the expected hypothetical mean of 22.50 for the total test and 11.25 for each operation, indicating weak initial mastery in integer operations. The findings indicate that subtraction of integers remained the most difficult competency for learners in the control group. This supports the findings of Basilio et al. (2023), who emphasized that integer operations continue to be a "Least Mastered Skill" among Filipino learners because students often depend on superficial rule memorization rather than conceptual understanding. The low baseline performance suggests that students lacked sufficient conceptual foundations in dealing with negative numbers and operational directionality.

3.1.2 Pretest Performance of the Experimental Group

The experimental group achieved an overall actual mean of 16.08 with a standard deviation of 5.03, interpreted as "Developing." In addition of integers, the group obtained a mean score of 10.42 interpreted as "Developing," while subtraction of integers recorded a mean of 5.67 described as "Beginning." Similar to the control group, the subtraction component showed the weakest performance among the respondents. The results indicate that both groups entered the study with comparable conceptual gaps, particularly in subtraction of integers. Hassan and Zaini (2022) explained that students commonly struggle when they fail to distinguish the direction of a number from its magnitude or absolute value. The similarity in low baseline performance confirms that both groups possessed nearly equivalent prior knowledge before the implementation of the intervention.

3.1.3 Difference Between the Pretest Performances of the Control and Experimental Groups

The comparison of pretest scores revealed no significant difference between the control and experimental groups in addition, subtraction, and overall integer operations performance. The p-values obtained for all comparisons were greater than the 0.05 level of significance, indicating that both groups had statistically comparable levels of mastery before the intervention. The absence of significant differences between the groups established a comparable baseline condition for the study. Jupri, Gozali, and Usodo (2021) noted that students who lack conceptual understanding of additive inverse and integer relationships commonly commit systematic errors, resulting in uniformly low achievement levels. The comparable baseline performance therefore strengthened the validity of the intervention results by confirming that no group possessed an initial advantage prior to the treatment.

3.2 Students' Posttest Performance in Integer Operations

3.2.1 Posttest Performance of the Control Group

Following traditional instruction, the control group achieved an overall actual mean of 20.39 with a standard deviation of 5.94, interpreted as "Developing." In addition of integers, the group obtained a mean score of 11.39 classified as "Proficient," while subtraction recorded a mean of 9.00 interpreted as "Developing." Although improvement was observed, the group failed to attain the overall hypothetical mean expectation of 22.50. The findings suggest that traditional instruction contributed to improvements in procedural fluency, particularly in addition of integers. However, subtraction remained difficult for many learners. Cho and Lee (2023) emphasized that instructional approaches lacking explicit conceptual justification often limit deeper mathematical understanding. The continued struggle in subtraction indicates that rote instruction alone may be insufficient in addressing conceptual difficulties involving negative integers and inverse operations.

3.2.2 Posttest Performance of the Experimental Group

The experimental group obtained an overall actual mean of 23.53 with a standard deviation of 4.68, interpreted as "Proficient." In addition of integers, the group achieved a mean of 13.11 classified as "Mastery," while subtraction of integers obtained a mean of 10.42 interpreted as "Proficient." The group exceeded the expected performance level in addition and demonstrated notable improvement in subtraction after exposure to the SDD Technique. The superior performance of the experimental group suggests that the SDD Technique effectively clarified the operational behavior of integers through conceptual and visual strategies. Sweller (1988) explained through Cognitive Load Theory that instructional strategies reducing unnecessary cognitive complexity improve student learning outcomes. By separating the solution process into Sign Dominance and Distance, the SDD Technique minimized cognitive overload and enabled learners to process integer operations more systematically. This finding is further supported by Park and Han (2024), who emphasized that instructional materials for integers should reduce cognitive complexity to improve mathematical understanding among middle school learners.

3.3 Difference Between the Posttest Performances of the Control and Experimental Groups

3.3.1 Difference in Addition of Integers Performance

The comparison of posttest scores revealed a significant difference in addition of integers between the control and experimental groups. The experimental group achieved a higher mean score of 13.11 compared to the control group's mean of 11.39, with a p-value lower than 0.05. The results indicate that the SDD Technique was highly effective in improving students' understanding of addition of integers. The concept of Sign Dominance enabled students to identify the stronger numerical value and determine the sign of the answer more intuitively. The improved performance demonstrates that learners benefited from a structured conceptual framework rather than relying solely on memorized rules.

3.3.2 Difference in Subtraction of Integers Performance

The experimental group obtained a higher mean score of 10.42 in subtraction compared to the control group's mean of 9.00. However, the difference between groups did not reach statistical significance because the p-value exceeded the 0.05 level of significance.Although improvement was evident, subtraction of integers remained cognitively demanding for students. Marrero and Frantz (2023) explained that learners often struggle with the relational understanding between subtraction and additive inverse, particularly in interpreting expressions such as A – B and A + (-B). The findings also align with OECD (2023) PISA results indicating that subtraction involving negative numbers continues to be a least mastered skill among learners because of its abstract and counterintuitive nature.

3.3.3 Difference in Overall Posttest Performance

The experimental group achieved a significantly higher overall posttest mean of 23.53 compared to the control group's mean of 20.39. Statistical analysis revealed a significant difference between groups since the p-value obtained was lower than the 0.05 level of significance. The findings confirm that the SDD Technique provided a greater academic advantage than Traditional Instruction in improving students' performance in integer operations. The intervention's emphasis on conceptual reasoning, number line manipulation, and structured problem-solving likely enhanced students' understanding and reduced computational confusion. The significant gains indicate that conceptual instructional scaffolds are more effective than purely procedural approaches in developing mathematical proficiency among Grade 7 learners.

3.4 Difference Within Groups Between Pretest and Posttest Performance

3.4.1 Improvement Within the Control Group

The control group demonstrated significant improvement between pretest and posttest performances across addition, subtraction, and overall scores. The overall mean increased from 13.97 during the pretest to 20.39 during the posttest, with effect sizes interpreted as medium to very large. The findings indicate that Traditional Instruction remained effective in improving students' procedural skills through repetition and practice. However, the magnitude of improvement was less pronounced compared to the experimental group. The gains observed in the control group represent the standard learning progression expected from continuous instruction and classroom exposure.

3.4.2 Improvement Within the Experimental Group

The experimental group demonstrated highly significant improvement between pretest and posttest performances in all categories. The overall mean increased from 16.08 during the pretest to 23.53 during the posttest. The largest improvement occurred in subtraction of integers, which produced a huge effect size of 2.06. The findings suggest that the SDD Technique served as a strong conceptual scaffold that accelerated student understanding and mastery of integer operations. Cho and Lee (2023) emphasized that instructional approaches providing explicit justification for each solution step generate larger achievement gains in mathematics. Similarly, Li, Yuen, and Lau (2020) found that self-explanation strategies improve knowledge acquisition and retention compared to rote memorization. The use of manipulative number lines also supports the findings of Tunc-Pekkan (2021), who reported that movement-based number line visualization improves learners' understanding of integer directionality and displacement.

4. Conclusion and Recommendations

The study concluded that Grade 7 students demonstrated significant conceptual gaps in integer operations, particularly in subtraction, prior to the intervention. Both groups initially performed at low proficiency levels, confirming comparable baseline understanding. After the implementation of the instructional strategies, both groups improved; however, the experimental group exposed to the Sign Dominance and Distance (SDD) Technique achieved higher posttest performance and greater internal growth than the group taught through traditional instruction. The findings indicate that the SDD Technique was more effective in improving conceptual understanding and procedural fluency because it simplified integer operations into logical and visual steps involving sign dominance and distance. Despite these improvements, subtraction of integers remained a challenging competency, suggesting that learners require more extensive conceptual scaffolding and continued exposure to fully master the operation.

Mathematics teachers are encouraged to integrate the Sign Dominance and Distance (SDD) Technique into Grade 7 instruction as an alternative to traditional rote-based methods in teaching integer operations. School administrators should support the implementation of professional development programs and workshops to equip teachers with the necessary skills in applying the SDD procedure and utilizing manipulative number lines effectively. Instructional materials and lesson plans should emphasize conceptual scaffolding and visual representations to strengthen students' understanding of integers. Furthermore, extended intervention activities focusing on subtraction of integers should be developed to address persistent conceptual difficulties and improve mastery among learners.

The study was limited to two intact Grade 7 classes from Calamba National Comprehensive High School during the School Year 2025–2026, which may affect the generalizability of the findings to other schools and grade levels. The quasi-experimental design utilized non-random assignment of participants, limiting the ability to establish strong causal inferences. The intervention was also conducted within a short period, which may not fully capture long-term retention and mastery of integer operations, particularly subtraction. In addition, the study focused only on addition and subtraction of integers and excluded multiplication and division operations.

Compliance with ethical standards

The authors declare no conflict of interest and confirm that this study received no external funding. The study was conducted with the approval and cooperation of Calamba National Comprehensive High School and the concerned educational authorities, and the researchers sincerely acknowledge the participation of the Grade 7 students and their parents or guardians. Participation in the study was voluntary, and informed consent and student assent were obtained prior to data collection using non-invasive educational assessments and classroom-based instructional activities. All collected data were treated with strict confidentiality, and no identifying information of the participants was disclosed in any part of the study.

REFERENCES

Ashman, G. (2021). *Cognitive load theory in action*. John Catt Educational.

Ayebale, L., Habyarimana, J. D., & Mugabo, K. (2026). *Factors affecting students' achievement in mathematics in secondary schools in developing countries: A rapid systematic review*. ResearchGate.

Basilio, J., et al. (2023). *Assessing students' mastery and misconceptions in the fundamental operations on integers*.

Burns, M. K., et al. (2025). Meta-analysis of procedural fluency and magnitude-based reasoning in integer operations. *Journal of Numerical Cognition*.

Center for Mathematical Cognition. (2026). *Spatial-numerical mapping and the expansion of the mental number line in secondary learners*. CMC Press.

Cho, & Lee. (2023). *Explicit justifications for procedural steps in middle school mathematics*.

Dela Cruz, M. (2023). *Numeracy gaps in rural Philippine secondary schools: A policy review*. Philippine Institute for Development Studies.

Dube, & Robinson. (2018). *Procedural learning and conceptual analysis in integer operations*.

Frontiers in Psychology. (2026). Visualizations during arithmetic tasks hamper performance and increase cognitive load: An fNIRS study. *Frontiers in Psychology, 17*, 102.

Grenell, A., Butts, J. R., Levine, S. C., & Fyfe, E. R. (2024). Children's confidence on mathematical equivalence and fraction problems. *Journal of Experimental Child Psychology, 246*, 106003. https://doi.org/10.1016/j.jecp.2024.106003

Gusenbauer, M., & Gauster, H. (2025). *Magnitude-based reasoning: A systematic review*. Contemporary Educational Research.

Hansen, T., et al. (2024). Metacognitive monitoring and procedural choice in signed number operations. *Journal of Educational Psychology*.

Harun, N. A., Cuevas, K. G., Asakil, O., Alviar, J., & Solon, L. J. (2023). Assessing students' mastery and misconceptions in the fundamental operations on integers. *International Journal of Science, Technology, Engineering and Mathematics, 3*(1), 36–55. https://doi.org/10.53378/353000

Hassan, & Zaini. (2022). *Decoupling number direction from magnitude in student errors*.

Heffington, J., et al. (2023). *Innovative teaching strategies in mathematics education*. MDPI Education Sciences.

IERJ. (2025). Cognitive load theory in mathematics learning: A comprehensive review for school-level application. *International Education and Research Journal, 11*(4), 55–62.

Jupri, Gozali, & Usodo. (2021). *Systematic errors and the additive inverse conceptual anchor*.

Khalid, & Embong. (2019/2020). *Sources and causes of misconceptions in integer operations*.

Kilpatrick, J., Swafford, J., & Findell, B. (Eds.). (2025). *Adding it up: Helping children learn mathematics* (Updated ed.). National Academies Press.

Kwok, F. Y., Wilkey, E. D., Peters, L., Khiu, E., Bull, R., Lee, K., & Ansari, D. (2023). Developmental dyscalculia is not associated with atypical brain activation: A univariate fMRI study of arithmetic, magnitude processing, and visuospatial working memory. *Human Brain Mapping, 44*(18), 6308–6325. https://doi.org/10.1002/hbm.26495

Küçüktaş, S., & St. Jacques, P. L. (2025). The impact of psychological distance on abstract thinking. *Memory & Cognition*.

Li, Yuen, & Lau. (2020). *Self-explanation and knowledge acquisition in mathematics*.

Marrero, & Frantz. (2023). *Relational understanding of equivalence in integer subtraction*.

McNeil, N. M., & Alibali, M. W. (2024). The "freed resources" mechanism in algorithms. *Journal of Numerical Cognition*.

National Academies of Sciences, Engineering, and Medicine. (2025). *The strands of mathematical proficiency: Conceptual understanding and procedural fluency*. The National Academies Press.

OECD. (2023). *PISA results regarding deep-seated conceptual hurdles in mathematics*.

Pajot, A., et al. (2025). *Dissociation of size and distance effect in numerical magnitude*. PMC PubMed Central.

Pandey. (2017). *Integer operations as a foundation for higher mathematics*.

Pariño, K. R., Canoy, M. V., & Augusto, M. I. (2025). Navigating the challenges: Students' skills and confusion in integer operations. *European Journal of Education Studies, 12*(12). https://doi.org/10.46827/ejes.v12i12.6451

Philippine E-Journals. (2021). Enhancing the basic operation performance in integers through the use of Krypto Games. *Apad National High School Research Journal*.

Park, & Han. (2024). *Minimizing cognitive complexity in middle school instructional materials*.

Ramos, L., et al. (2021). Pedagogical approaches to numerical thinking. *Journal of Basic Education Research*.

RePEc. (2024). *Strategic intervention report: Grade 7 integer performance*. Economic and Educational Policy Review.

Santos, A. R. (2022). *Peer-tutoring and procedural mastery in Junior High School Mathematics* (Unpublished master's thesis).

Sweller, J. (1988). *Cognitive load theory and instructional design*.

Tan, L., & Nguyen, H. (2025). Retention of mathematical procedures: A longitudinal comparison of rote vs. logic-based instruction. *International Journal of Science and Mathematics Education*.

Tunc-Pekkan. (2021). *Simulating movement on a number line for integer directionality*.

Villarreal, J. C., & Tan, E. (2024). Cognitive load and math anxiety: Implications for the MATATAG curriculum. *Journal of Philippine Education Reform*.

Vlassis, J. (2002). *The role of the number line in reconciling abstract negative numbers*.

Vosniadou, S., et al. (2025). *International handbook of research on conceptual change* (Updated ed.). Routledge.

Zuhriawan, A., et al. (2024). A didactical transposition study on secondary students' number sense of integers. *Frontiers in Education*. https://doi.org/10.3389/feduc.2026.1739073