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Research Article

ENHANCING STUDENTS' MASTERY OF INTEGER OPERATIONS THROUGH A COLLABORATIVE LEARNING STRATEGY USING KENKEN PUZZLES

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Abstract

This study investigated the effectiveness of the Collaborative Learning Strategy (CLS) using KenKen Puzzle in enhancing Grade 8 students' mastery of integer operations at SHS- 01. Employing a quasi-experimental pre-test and post-test control group design, the study involved two sections selected through multi-stage cluster sampling, with one section randomly assigned as the control group and the other as the experimental group. Both groups took a researcher-made, validated 50-item test before and after the intervention. The control group received traditional instruction, while the experimental group participated in a six-session intervention to promote interactive and meaningful learning of integer addition, subtraction, multiplication, and division. Data were analyzed using mean percentage score, standard deviation, paired t-test, independent samples t-test, and Cohen's d to determine improvement and effect size. Results showed that while the control group had minimal gains, the experimental group demonstrated a statistically significant improvement with a large effect size. These findings indicate that the intervention effectively enhances students' mastery of integer operations while promoting greater engagement and collaborative problem-solving in mathematics classrooms.

Keywords: Collaborative Learning Strategy, Integer Operations, KenKen Puzzle

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INTRODUCTION

Mastery of integer operations is fundamental in Mathematics, serving as a prerequisite for higher-level learning and real-world problem-solving. However, many students struggle with these operations due to conceptual misunderstandings and procedural errors, particularly in mixed operations where numbers are treated as abstract symbols (Hanifa et al., 2024). Such difficulties impede students' fluency and contribute to low performance in Mathematics.

International and local studies reveal similar challenges. In Turkey, students relying on algorithmic procedures exhibit slower and less accurate performance compared to those using conceptual strategies (Ulu & Ozdemir, 2019). In Indonesia, common errors include omission of negative signs and sequencing mistakes (Baharuddin et al., 2021). In the Philippines, modular learning has weakened students' foundational skills, with persistent misconceptions and procedural errors in integer subtraction (Harun et al., 2023; Valmoria & Tan, 2019). In Davao de Oro, the transition to modular and online learning environments reduced opportunities for guided practice and immediate feedback, which are essential in learning integer operations. As a

result, students struggled to correct misconceptions, leading to persistent errors in signed-number computations (Maatuk et al., 2022).

Cooperative and collaborative learning strategies have shown potential in addressing these issues by promoting conceptual understanding and engagement (León, 2019). Among such tools, KenKen puzzles provide an interactive platform for practicing integer operations, enhancing reasoning and problem-solving skills (Reiter et al., 2013). Despite their promise, limited research has explored the integration of the Collaborative Learning Strategy (CLS) with KenKen puzzles. Given these challenges, the core concern of this study is the students' limited mastery of integer operations, particularly their difficulties in adding, subtracting, multiplying, and dividing integers accurately. The weakened feedback mechanisms during modular and online learning further contributed to misconceptions and inconsistent computational skills in integer operations.

Review of Related Literature

Integers are fundamental in Mathematics as they allow representation of both positive and negative quantities, making them essential in solving real-world problems such as measuring temperature, calculating profit and loss, and analyzing quantitative relationships (Setyawati & Indiati, 2018). Mastery of integer operations—addition, subtraction, multiplication, and division—forms the foundation for higher mathematical learning, ensuring accuracy in computation and problem-solving (Nurnberger-Haag et al., 2022; Sharma, 2024). Proficiency in these operations is crucial since errors at this level can hinder students' progression in more abstract topics such as algebra and equation solving (Duque et al., 2025).

However, many students experience difficulties with integer operations due to conceptual misconceptions, especially with negative numbers, and procedural errors in applying rules (Khalid & Embong, 2019; Alfarisi et al., 2022). These struggles are compounded by overreliance on memorized algorithms, lack of deep understanding, and low engagement in mathematics learning (Amaliyah et al., 2022). Learners often fail to apply the correct order of operations and misinterpret the meaning of signs in mixed operations, leading to confusion and frequent mistakes (Unaenah et al., 2023). Addressing these difficulties requires the use of innovative and interactive approaches that promote conceptual understanding and sustained motivation.

Collaborative Learning Strategy is grounded in the principle that learning is a social process where students actively construct knowledge through interaction, discussion, and shared problem-solving (Jacobs & Renandya, 2019; Brown & Palincsar, 1989). It encourages learners to work together, exchange ideas, and justify their reasoning, thereby fostering communication, critical thinking, and reflective learning (Chamberland et al., 2020). In mathematics education, this strategy has been shown to improve students' performance and engagement as they collectively tackle problems and learn from peers (Olanrewaju, 2019).

Moreover, collaborative learning enhances essential affective traits such as motivation, self-esteem, and sense of responsibility among students (Cabalquinto & Magallanes, 2022; Agustin, 2021). It provides learners with opportunities to assess their understanding, give peer feedback, and develop persistence in solving mathematical problems (Gillies, 2016). Studies affirm that this approach helps sustain interest and retention by transforming learning into an interactive, student-centered experience. Thus, CLS creates a supportive environment that allows learners to engage deeply with mathematical content and develop both cognitive and social competencies.

KenKen is a logic-based mathematical puzzle developed to strengthen arithmetic skills, problem-solving, and reasoning (Reiter et al., 2013). Similar to Sudoku, it requires players to fill a grid using basic operations—addition, subtraction, multiplication, and division—without repeating numbers within a row or column (Nacin, 2022). KenKen puzzles are proven to enhance number sense, procedural fluency, and logical reasoning while encouraging productive struggle and perseverance (Murawska, 2018; Passolunghi et al., 2020). The engaging nature of puzzle-based learning supports the development of mathematical confidence and reduces anxiety toward computation.

Recent studies highlight that incorporating KenKen puzzles in instruction promotes student engagement, collaboration, and creativity (Molina & Ibañez, 2024). Learners report increased enjoyment and motivation while reinforcing core concepts in integer operations. Game-based instruction using KenKen aligns with findings that interactive and enjoyable activities strengthen students' cognitive and affective outcomes in Mathematics (Salviejo et al., 2024; Dela Cruz & Roleda, 2019). By combining entertainment with learning, KenKen offers an effective avenue for fostering positive attitudes and deepening conceptual understanding among

students.

While collaborative learning and puzzle-based instruction have individually shown significant benefits in mathematics education, few studies have examined their combined effects on students' mastery of integer operations. Research seldom explores how integrating Collaborative Learning Strategy (CLS) with KenKen puzzles can enhance conceptual understanding, engagement, and problem-solving skills simultaneously. Addressing this gap, the present study investigates the effectiveness of CLS integrated with KenKen puzzles in improving Grade 8 students' mastery of integer operations compared to traditional teaching approaches.

Research Questions and Significance of the Study

This study aimed to determine the effectiveness of the Collaborative Learning Strategy (CLS) using KenKen puzzles in enhancing students' mastery of integer operations. Specifically, it sought to answer the following questions:

1. What is the level of students' mastery in solving integer operations before the implementation of the Collaborative Learning Strategy using KenKen puzzles?
2. What is the level of students' mastery in solving integer operations after the implementation of the Collaborative Learning Strategy using KenKen puzzles?
3. Is there a significant difference in the students' mastery of integer operations before and after the implementation of the intervention?
4. Is there a significant difference in the post-test scores of students exposed to the intervention and those taught through traditional instruction?

The significance of this study lies in its contribution to improving mathematics instruction through innovative, student-centered approaches. By integrating the Collaborative Learning Strategy (CLS) with KenKen puzzles, the study promotes active engagement, critical thinking, and conceptual understanding of integer operations. The findings may assist mathematics teachers in designing interactive learning experiences, help academic institutions in developing effective remedial and enrichment programs, and serve as a reference for future researchers exploring collaborative and game-based strategies to enhance mathematical proficiency.

METHODS

Research Design

This study utilized a quasi-experimental pre-test–posttest control group design to examine the effectiveness of the Collaborative Learning Strategy (CLS) using KenKen puzzles in enhancing Grade 8 students' mastery of integer operations at SHS- 01. Two comparable sections were selected through multi-stage cluster sampling and randomly assigned as the control and experimental groups. A researcher-made, expert-validated 50-item test served as the primary instrument to assess students' proficiency before and after the intervention. The experimental group received six sessions of CLS-integrated instruction using KenKen puzzles, while the control group was taught through traditional methods. Data were collected through the administration of pretests and posttests, ensuring consistency in test administration and scoring procedures. The gathered data were analyzed using descriptive statistics (mean and standard deviation) and inferential statistics (paired t-test, independent samples t-test, and Cohen's d) to determine the significance and magnitude of the intervention's effect on students' mastery of integer operations.

Research Locale and Respondents/Participants

The study was conducted at a public secondary school in Davao de Oro, coded as SHS-01, to maintain institutional anonymity. The school provides a conducive learning environment with adequate facilities that support collaborative and innovative instructional practices. The participants of the study were Grade 8 students enrolled during the School Year 2024–2025. Using multi-stage cluster sampling, two of the four Grade 8 sections with comparable levels of mathematical proficiency were selected and randomly assigned as the control and experimental groups. Each group consisted of approximately 40 students, ensuring a sufficient sample size for statistical analysis. Participation was voluntary, with informed consent secured from both students and their parents. The selection of this locale and participant group was based on their accessibility, willingness to participate, and the identified need to strengthen mastery of integer operations among junior high school learners.

Research Instrument

The primary research instrument used in this study was a researcher-made, 50-item test designed to measure students' mastery of integer operations,

specifically addition, subtraction, multiplication, and division. The test items were constructed based on the Grade 8 Mathematics curriculum standards to ensure alignment with learning competencies. To establish content validity, the instrument underwent expert validation by mathematics educators and research specialists, who reviewed each item for clarity, relevance, and accuracy. A pilot test was also conducted to ensure reliability and determine item difficulty and discrimination indices. The instrument was administered as both the pretest and posttest to assess students' performance before and after the implementation of the Collaborative Learning Strategy (CLS) using KenKen puzzles. The results served as the primary quantitative data for analyzing improvements in students' mastery and determining the effectiveness of the intervention.

Data Gathering Procedure

The data collection process followed a systematic sequence to ensure validity, reliability, and ethical compliance. Prior to implementation, the researchers secured approval from the Davao de Oro State College Research Ethics Committee and obtained permission from the principal of SHS-01. Informed consent forms were distributed to participating students and their parents, emphasizing voluntary participation and confidentiality. A pretest was first administered to both the control and experimental groups to determine their baseline mastery of integer operations. The experimental group then underwent a six-session intervention using the Collaborative Learning Strategy (CLS) integrated with KenKen puzzles, while the control group received traditional instruction. To support the Collaborative Learning Strategy (CLS), KenKen puzzles were integrated into the five-session intervention (excluding the pretest and posttest). KenKen puzzles are logic-based arithmetic grids where each row and column must contain non-repeating numbers while satisfying the operations indicated in outlined cages. The puzzles used in this study ranged from 3×3 to 5×5 grids and required students to perform integer addition, subtraction, multiplication, and division to complete each cage. During each session, students worked collaboratively in small groups, discussing possible number combinations, checking for rule consistency, and justifying their reasoning. This process encouraged peer explanation, conceptual clarification, and cooperative problem-solving. A sample KenKen puzzle was included in this article to illustrate the structure of the grids and the placement of operation-based cages, making the nature of the activity clearer to readers.

Intervention Sessions

The intervention followed a structured sequence combining direct instruction, guided practice, and collaborative problem-solving.

Session 1 introduced the rules and structure of KenKen puzzles, followed by a 3×3 simulation to familiarize students with puzzle-solving procedures.

Session 2 focused on integer addition through 4×4 KenKen puzzles solved in small collaborative groups.

Session 3 covered subtraction using 4×4 puzzles, with students working in pairs and sharing solutions to clarify misconceptions.

Session 4 targeted multiplication using 5×5 puzzles solved in trios, emphasizing factor identification and sign rules.

Session 5 addressed division using both 4×4 and 5×5 puzzles, with larger groups collaborating and presenting their approaches.

Throughout the intervention, the researchers monitored class activities to ensure consistency and adherence to the designed procedures. After the sessions, a posttest identical to the pretest was administered to measure learning gains. All test papers were collected, scored, and tabulated for statistical analysis. The entire process was completed within the second quarter of the academic year 2024–2025.

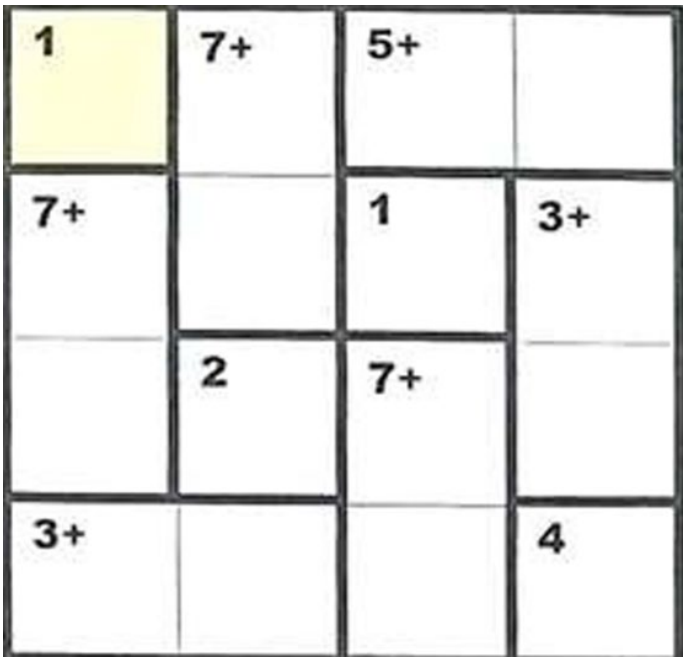


Figure 1. Sample KenKen Puzzle Used in the Intervention

Data Analysis

The gathered data were analyzed using both descriptive and inferential statistical techniques to evaluate the effectiveness of the Collaborative Learning Strategy (CLS) using KenKen puzzles in enhancing students' mastery of integer operations. Descriptive statistics, including the mean and standard deviation, were computed to determine students' average performance and variability in pretest and posttest scores. Inferential analyses were conducted using a paired t-test to compare the pretest and posttest scores within each group, and an independent samples t-test to determine the significance of the difference between the control and experimental groups after the intervention. Cohen's d was also computed to measure the magnitude of the effect of the intervention. Statistical analyses were performed at a 0.05 level of significance to ensure reliability and validity of the results, allowing for accurate interpretation of the CLS with KenKen puzzles' impact on students' mathematical performance.

Ethical Considerations

This study strictly adhered to the ethical standards set by the Davao de Oro State College Research Ethics Committee to ensure the integrity and protection of all participants. Prior to data collection, ethical clearance was obtained, and formal permission was sought from the principal of SHS- 01. Informed consent forms were distributed to students and their parents, clearly stating the purpose of the study, the voluntary nature of participation, and the assurance of confidentiality and anonymity. Participants were informed of their right to withdraw at any stage without penalty. The researchers ensured that no physical, psychological, or emotional harm would result from participation, and all collected data were treated with utmost confidentiality and used solely for academic purposes. Proper acknowledgment of all sources and avoidance of plagiarism, falsification, and fabrication was strictly observed throughout the research process.

RESULTS AND DISCUSSION

Level of students' mastery in solving integer operations before the intervention

Table 1 presents the pre-test results of both groups, showing the students' initial level of mastery in integer operations prior to the implementation of the intervention. It can be gleaned from the table that the control group obtained a mean score of 14.77 (*SD = 4.72*) and the experimental group a mean score of 14.13 (*SD = 4.98*), both interpreted as Low Mastery. This indicates that prior to the intervention, students had limited understanding of integer operations and exhibited similar levels of proficiency. The comparable pretest means confirm that both groups started with nearly equal capabilities, fulfilling the assumption of group equivalence necessary for quasi-experimental design.

The pretest findings revealed that both the control and experimental groups exhibited Low Mastery in integer operations, confirming that students struggled with the basic rules governing positive and negative numbers. This result reflects the common misconceptions identified by Khalid and Embong (2019) and Alfarisi et al. (2022), who noted that learners often rely on rote memorization rather than conceptual understanding when performing integer operations. The nearly identical pretest means also establish that both groups started from equivalent levels of proficiency, ensuring the validity of the subsequent comparison. This baseline weakness underscores the importance of using innovative and interactive instructional strategies that target conceptual clarity before advancing to more abstract mathematical topics.

Table 1. Level of students in solving integer operations prior to the implementation of the Collaborative Learning Strategy (CLS) using KenKen Puzzles

	Mean	Standard Deviation	Descriptive Level
Control Group	14.77	4.72	Low Mastery
Experimental Group	14.13	4.98	Low Mastery

Level of students' mastery in solving integer operations before the intervention

After the intervention, a significant increase in the experimental group's mean score was observed. As shown in Table 2, the experimental group attained a posttest mean of 33.35 (*SD = 5.68*), interpreted as Moving Towards Mastery, while the control group obtained a mean of 16.64 (*SD = 2.87*), which remained within the Low Mastery range. These results indicate that students exposed to the CLS with KenKen puzzles demonstrated greater improvement in conceptual understanding and computational

accuracy than those who received traditional instruction.

After the intervention, the experimental group's mastery significantly improved, progressing from Low Mastery to Moving Toward Mastery, while the control group's level remained unchanged. This demonstrates that integrating the Collaborative Learning Strategy (CLS) with KenKen puzzles effectively enhances students' understanding and performance in integer operations. The result aligns with the findings of Molina and Ibañez (2024), who reported that puzzle-based collaborative learning promotes engagement and problem-solving accuracy. Similarly, Passolunghi et al. (2020) emphasized that enjoyable, game-based activities reduce math anxiety and foster persistence. By combining peer collaboration and puzzle-solving, the CLS with KenKen approach created a dynamic and meaningful learning environment where students could actively construct knowledge rather than passively receive information.

Table 2. Level of Students' Mastery in Solving Numerical Expressions with Integers after the Intervention

	Mean	Standard Deviation	Descriptive Level
Control Group	16.64	2.87	Low Mastery
Experimental Group	33.35	5.68	Moving Towards Mastery

Difference in Mastery of Integer Operations During Pre and Post-Test Within Experimental and Control Groups

Table 3 displays the comparison of pre- and post-test results within each group, highlighting the extent of improvement in students' performance following the intervention. Paired t-test results reveal a significant improvement in the experimental group's posttest performance, $t(30) = 18.88, p < .001$, with a large effect size ($d = 3.31$). Conversely, the control group's performance showed no significant difference between pretest and posttest, $t(21) = 1.99, p = .060$. These findings confirm that the CLS intervention effectively enhanced students' mastery of integer operations, while traditional instruction yielded only minimal gains.

The significant within-group difference observed in the experimental group's pretest and posttest scores further confirms the effectiveness of the intervention. The large effect size (*Cohen's d = 3.31*) indicates that the CLS with KenKen puzzles produced a substantial impact on students' learning outcomes. This improvement can be attributed to the structured interaction and feedback mechanisms inherent in collaborative learning, which Johnson and Johnson (2018) identified as critical for improving conceptual understanding. The social nature of CLS allowed learners to discuss and clarify misconceptions, while the KenKen puzzles served as an application tool that linked theory to practice. This supports Vygotsky's (1978) Social Constructivist Theory, particularly the Zone of Proximal Development, where learning occurs most effectively through guided peer interaction and problem-solving tasks.

Table 3. Pre-Post Test Differences in Integer Operation Mastery Within Groups

Comparison	*t*	*df*	*p*	Cohen's *d*	Remarks
Control Group (*Pretest vs Post-test*)	1.99	21	0.060	0.42	Not Significant
Experimental Group (*Pretest vs Post-test*)	18.88	30	<0.001	3.31	Not Significant

Difference in Mastery of Integer Operations During Post-Test Between Experimental and Control Groups

Table 4 shows the comparison of post-test scores between the experimental and control groups, indicating whether the intervention led to significantly higher mastery compared to traditional instruction. Results of the independent samples t-test show a significant difference in posttest scores between the experimental and control groups, $t(46.83) = 14.06, p < .001$, with a very large effect size ($d = 3.92$). This indicates that the experimental group significantly outperformed the control group, confirming that the CLS with KenKen puzzles was highly effective in improving mastery of integer operations.

When comparing the two groups' posttest results, the experimental group significantly outperformed the control group, indicating that CLS with KenKen

puzzles is superior to traditional instruction in enhancing mastery of integer operations. The effect size comparing the post-test performance of the experimental and control groups (*Cohen's d = 3.92*) represents a very large and educationally significant impact. This value suggests that the students who experienced the CLS–KenKen intervention outperformed their peers in traditional instruction by a substantial margin. A Cohen's d of this magnitude indicates that the distributions of the two groups' scores barely overlap, demonstrating that the intervention had a powerful influence on students' mastery of integer operations. From an instructional perspective, this effect size reflects the effectiveness of collaborative learning and puzzle-based problem-solving in promoting deeper mathematical reasoning, sustained engagement, and improved computational accuracy. The result underscores the value of integrating structured collaboration and game-based activities in mathematics classrooms, as these approaches yield performance gains far greater than what would typically be expected from regular instruction. These findings are consistent with those of (Gillies, 2016), who found that collaborative learning improves mathematical retention, and Dela Cruz and Roleda (2019), who demonstrated that gamification increases motivation and engagement. The present study adds to the growing body of evidence supporting learner-centered, activity-based strategies as effective tools for addressing learning gaps in mathematics. Practically, this approach encourages critical thinking, teamwork, and enjoyment in problem-solving, contributing to improved mathematical fluency and confidence

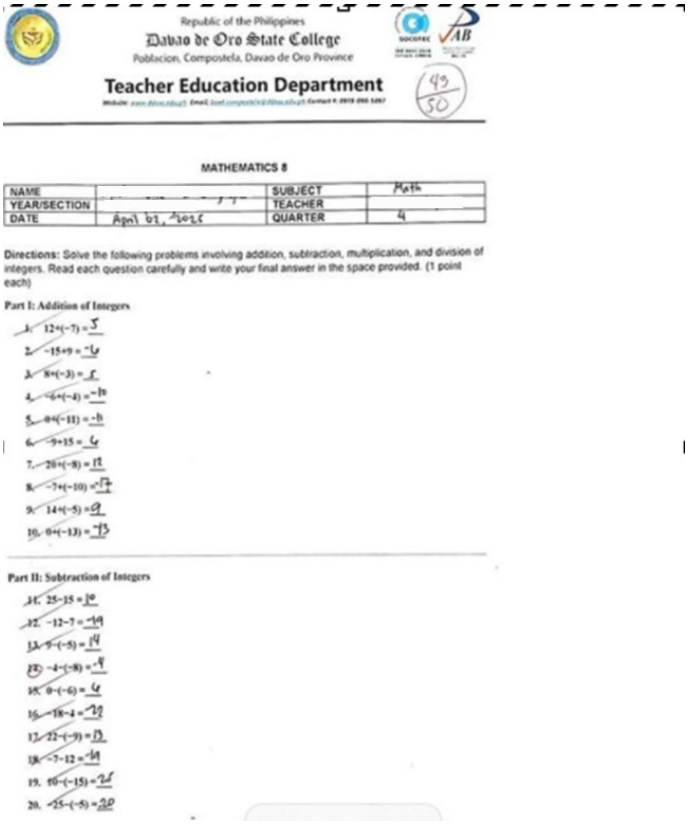
Table 4. Level of Students' Mastery in Solving Numerical Expressions with Integers after the Intervention

Assumption	Mean Difference	*t*	*df*	*p*	Cohen's *d*	Remarks
Unequal Variance	16.72	14.06	46.83	<0.001	3.92	Significant

Additional qualitative evidence strengthens the interpretation of the results. As illustrated in Figure 2, students in the experimental group actively collaborated during the CLS–KenKen sessions, discussing strategies, validating possible number combinations, and guiding one another through challenging cages. This collaborative behavior reflects a shift toward deeper reasoning and shared conceptual understanding. Evidence of this improvement is seen in Figure 3, which presents a sample post-test output showing more accurate and confident computation of integer operations. Unlike the initial difficulties observed before the intervention, students demonstrated fewer operational errors and showed improved consistency in applying integer rules. The clarity, correctness, and organization of the post-test responses suggest that learners not only mastered the procedures but also internalized the concepts through the structured peer interactions fostered by the KenKen puzzles.

In contrast, students in the control group, who continued using traditional instruction, were observed to rely heavily on memorized rules and often repeated procedural mistakes. These artifacts collectively reinforce the quantitative findings, confirming that the CLS–KenKen intervention enhanced computational accuracy, strengthened conceptual reasoning, and supported more effective learning compared to traditional instruction.

Figure 2. Students Collaboratively Solving a KenKen Puzzle During the CLS Intervention


Republic of the Philippines
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Poblacion, Compostela, Davao de Oro Province
Teacher Education Department
43/50
MATHEMATICS 8
NAME | SUBJECT | Math
YEAR/SECTION | TEACHER
DATE | April 01, 2025 | QUARTER | 4
Directions: Solve the following problems involving addition, subtraction, multiplication, and division of integers. Read each question carefully and write your final answer in the space provided. (1 point each)
Part I: Addition of Integers
1. 12+(-7) = 5
2. -15+9 = -6
3. 8+(-3) = 5
4. -6+(-4) = -10
5. 0+(-11) = -11
6. -9+15 = 6
7. 26+(-8) = 18
8. -7+(-10) = -17
9. 14+(-5) = 9
10. 0+(-13) = -13
Part II: Subtraction of Integers
11. 25-15 = 10
12. -12-7 = -19
13. 9-(-5) = 14
14. -4-(-8) = 4
15. 0-(-6) = 6
16. -18-4 = -22
17. 22-(-9) = 13
18. -7-12 = -19
19. 10-(-15) = 25
20. -25-(-5) = -20

Figure 3. Sample Student Output in the Post-Test After the CLS–KenKen Intervention

CONCLUSION

The findings of the study clearly demonstrate the effectiveness of the Collaborative Learning Strategy (CLS) using KenKen puzzles in improving students' mastery of integer operations. First, both groups initially exhibited low mastery based on their pre-test results, confirming the need for instructional support. After the intervention, the experimental group achieved a significantly higher level of mastery, while the control group remained within the low mastery range. The pre–post comparison further showed that only the experimental group achieved a statistically significant improvement with a very large effect size, indicating that the intervention had a strong and meaningful impact on students' mastery of integer operations. Lastly, the post-test comparison between groups revealed that students who received the CLS–KenKen intervention performed substantially better than those who received traditional instruction (RQ4). Overall, the study concludes that integrating CLS with KenKen puzzles is an effective instructional approach for strengthening students' mastery of integer operations.

Teachers are encouraged to apply the Collaborative Learning Strategy (CLS) using KenKen puzzles as a structured approach for improving students' mastery of integer operations. The intervention may be used particularly in lessons that require careful application of integer rules, as the puzzle-based format supports procedural accuracy and conceptual understanding. Effective implementation also requires thoughtful facilitation of group activities and intentional grouping to ensure meaningful participation. Future studies may explore the use of CLS with KenKen puzzles in other mathematical topics or examine its effectiveness in supporting long-term mastery.

Acknowledgement

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Conflict of Interest

The authors declare no conflict of interest

Ethical Statement

The study obtained clearance from DDOSC-REC with protocol code 238-02-2025.

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