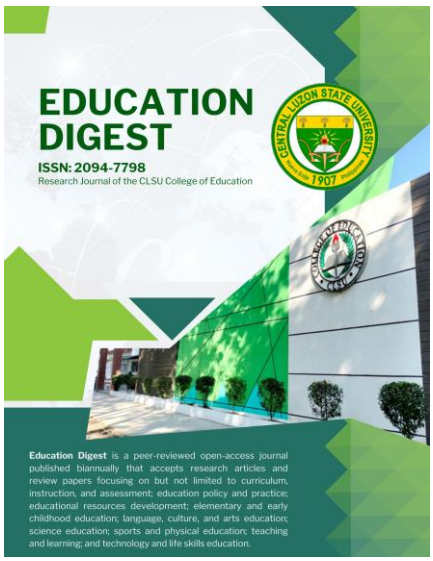

Students' Performance and Attitude in Operating Integers Using KenKen Puzzle in a Collaborative Learning Environment

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Research Article

Abstract: Using the KenKen puzzle may improve students' performance in operating integers. Quasi-experimental research was conducted to determine the effectiveness of this intervention on the performance and attitude of students in a collaborative learning environment. One hundred four purposively selected Grade 7 students in Nueva Ecija served as respondents and the experimentation lasted four days following the K to 12 Learners Manual. An increase in the student's performance was found after utilizing the KenKen puzzle, where a significant difference between the posttest and pretest was recorded after the four days of utilization of the puzzle. Besides, students' attitude toward operating integers showed positivity as it is enjoyable, interesting, challenging, and developing creativity and critical thinking. Moreover, a strong relationship was found between the students' performance and attitude in operating integers. This suggests that the KenKen puzzle helped improve the students' performance and attitude in operating integers in a collaborative learning environment.

Keywords: *instructional intervention, K-12 Curriculum, learning integers, mathematics education*

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Introduction

The K to 12 mathematics education aims to develop students' critical thinking and enhance their problem-solving skills. These goals are achieved through an organized and rigorous curriculum content, a well-defined set of high-level skills and processes, desirable values and attitudes, and appropriate tools, considering the diverse contexts of Filipino learners. Research has shown that students can learn the material effectively regardless of the method used, though enjoyment can significantly impact their overall academic success. Students who find the learning process enjoyable are likelier to retain the information (Allen & Rust, 2007). Teaching varied strategies can improve students' performance and foster positive dispositions toward learning (Bacsal et al., 2022; Ibañez & Pentang, 2021).

Teachers have increasingly incorporated games and puzzles in recent years to create a fun and engaging learning environment. This includes applying gamification techniques, such as performance badges, which can positively affect students' attitudes even if the badges do not impact grades (Dicheva, 2015). Aligned with the Department of Education's mission to create student-centered learning, teachers focus on developing students' skills and improving their performance through interactive and collaborative strategies. Collaborative learning, often involving games or puzzles, tends to be more productive than competitive or individualistic methods. It typically results in higher performance, greater productivity, more supportive relationships, and improved psychological health, social competence, and self-esteem (Laal & Ghodsi, 2011).

Building on the foundation of collaborative learning strategies, this study employed the KenKen puzzle as an intervention to help students improve their arithmetic skills in mathematics. Specifically, the focus was on the performance of Grade 7 students at Maligaya National High School in Nueva Ecija, particularly in operating integers. This intervention is critical as the Philippines faces significant challenges regarding students' competency in mathematics. The country has lagged in international assessments such as the Trends in International Mathematics and Science Study and the Programme for International Student Assessment (PISA). Furthermore, in the National Achievement Test, Region III's Mean Percentage Score (MPS) for Grade 6 was 73.39% in 2015. At Maligaya National High School, the MPS for Mathematics was 78.06% in 2015 but showed a declining trend in subsequent years: 73.61% in 2018-2019, 64.24% in 2017-2018, and 62.20% in 2016-2017. Fundamental operations on integers, such

as addition, subtraction, multiplication, and division, were consistently identified as the least-learned skills. Addressing these fundamental difficulties is essential for students progressing in algebra and higher-level mathematics. Therefore, this study was conceptualized to determine students' performance and attitudes after using the KenKen puzzle to enhance their knowledge and skills in fundamental operations on integers.

Research Questions

This study sought to determine the difference and relationship between students' performance and attitude in operating integers using KenKen puzzles before and after instruction in a collaborative learning environment. Specifically, this study aimed to answer the following questions:

(1) What is the student's performance in operating integers before and after instruction?
(2) Is there a significant difference between students' performance in operating integers before and after instruction?
(3) What is the attitude of the respondents in operating integers after instruction?
(4) Is there a significant relationship between the student's performance and attitude in operating integers after instruction?

Methodology

Research Design and Sample

The study used quasi-experimental research where a pretest-posttest design was undertaken. This research resembles instructional experimentation where the independent variable is manipulated, and participants are not randomly assigned to conditions or order of conditions (Cook & Campbell, 1979). This is usually undertaken to determine the effectiveness of an intervention. In this method, the group was pretested about operations on integers. Afterward, treatment was utilized at a specific time. Then, a posttest was undertaken to determine their performance as a result of the experimentation. The comparison in the performance comes from examining the subjects' values on the outcome of the pretest and posttest after the exposure. If posttest values differ from pretest values, a case can be made that the treatment was the cause of the change. This study also used the descriptive research method to describe the attitude in operating integers after instruction. The sample comprised 104 students from five sections from Maligaya National High School, categorized by performance levels as beginning (grades ≤ 74%), developing (grades 75–80%), and approaching proficient (grades 81–84%) as per D.O. 43, s 2013. A purposive sampling technique was used in this study. This technique was used in selecting the study's respondents since sampling for proportionality was not the primary concern.

Data Collection and Instruments

Following the approval of the research proposal and authorization from the Office of the Schools Division Superintendent in Nueva Ecija, the study was conducted over six days. The timeline included one day for pretesting, four days for the KenKen puzzle intervention, and one day for post-testing. A six-page questionnaire assessed students' performance and attitudes before and after the intervention. The study primarily utilized the KenKen puzzle as an intervention tool to enhance students' skills in operating integers within a collaborative learning environment. Instructional interventions are necessary to address mathematics learners' needs and aspirations (Aguhayon et al., 2023; Azucena et al., 2022).

The researcher-made instrument consisted of two parts. The first part focused on assessing students' performance through pretest and posttest evaluations, while the second part gauged students' attitudes toward operating integers after the intervention. The researcher employed expert reviews and iterative refinement to validate the instrument's content. The instrument's reliability was determined using the Kuder-Richardson formula 21, which yielded a reliability coefficient 0.703 for the comprehensive tests. This value indicates that the test is reasonably reliable in producing consistent scores. The intervention involved maximizing the use of the KenKen puzzle to improve students' performance in operating integers. Students engaged in collaborative learning activities facilitated by the teacher and structured around solving KenKen puzzles. This approach aimed to create an interactive and supportive learning environment that fostered skill development and positive attitudes toward mathematics.

Data Analysis

The collected and tabulated data were checked and verified for missing data, outliers, normality, homoscedasticity, and multicollinearity. Frequency, mean, and age were used to describe the students' performance before and after instruction and the attitude in operating integers to determine the students' agreeableness level. In addition, a paired sample t-test was used to determine the difference between students' performance before and after instruction (Pentang, 2021). More so, Pearson's *r* correlation was used to determine if a significant relationship exists between students' performance and attitude in operating integers after instruction.

Results and Discussion

Students' Performance Before and After Instruction

Before instruction, results revealed that 51.92% of the students had low mastery in operating integers, 32.69% had average mastery, 11.54% had very low mastery, and 2.89% were moving towards mastery, while 0.96% had no mastery. None of the respondents were categorized as closely approaching mastery or better. This indicates that most respondents had low mastery in operating integers at the beginning of the study despite the lesson being covered during the First Quarter. These findings suggest that the student's skills in operating integers were not fully developed, with very few moving toward mastery. This calls for a quasi-experimental research method to address the deficiency in students' understanding of integer operations. Such methods, often involving interventions to enhance student performance and assess their effectiveness in teaching and learning, have been used in similar studies by Azucena et al. (2022) and Derraco (2017).

After instruction in a collaborative learning environment, students' performance improved significantly. The results showed that 51.92% of the respondents were moving towards mastery in operating integers, 25.96% had average mastery, and 9.62% had low mastery. Additionally, 5.77% were closely approaching mastery, and another 5.77% had very low mastery. Notably, 0.96% of the students achieved complete mastery, and none of the respondents were reported with no mastery. These outcomes imply that most respondents improved their performance post-instruction, demonstrating the effectiveness of the intervention in enhancing their skills in operating integers.

The marked improvement in students' performance after instruction highlights the efficacy of the collaborative learning environment and targeted interventions. Initially, most students exhibited low to average mastery in operating integers, indicating a significant gap in their understanding. However, after the intervention, there was a substantial shift towards higher levels of mastery. This underscores the potential of well-designed instructional strategies to address educational deficiencies. The findings suggest collaborative learning can significantly enhance students' comprehension and application of mathematical concepts, advocating for its broader implementation in educational settings. Furthermore, continuous assessment and adaptation of teaching methods are crucial to meet students' evolving needs and ensure academic success.

Table 1. The student's performance before and after instruction.

Levels Of Performance	Before Instruction		After Instruction	
	frequency	%	frequency	%
No mastery	1	0.96	0	0
Very low mastery	12	11.854	6	5.77
Low mastery	54	51.92	10	9.62
Average mastery	34	32.69	27	25.96
Moving towards mastery	3	2.89	54	51.92
Approaching mastery	0	0	6	5.77
Mastered	0	0	1	0.96
Total	104	100	104	100

Differences in the Students' Performance Before and After Instruction

The posttest scores (M = 9.79, SD = 3.67) were significantly higher than the pretest scores (M = 4.94, SD = 2.49), t = -13.89, p < .001 (Table 2). This significant increase suggests that, without the intervention, students' performance would likely have remained unchanged. The significant increase in posttest scores compared to pretest scores indicates that the intervention substantially impacted students' mastery of integer operations. This improvement underscores the effectiveness of employing collaborative learning environments and targeted interventions to address specific educational deficiencies. The findings align with a broad spectrum of research highlighting the benefits of innovative teaching strategies, manipulatives, and engaging activities in enhancing mathematical understanding (Aguhayon et al., 2023; Azucena et al., 2022). As students demonstrated marked progress in their post-instruction performance, it is evident that such educational approaches can bridge gaps in foundational skills and foster a more profound comprehension of mathematical concepts. This study reaffirms the value of collaborative and intervention-based teaching methods and emphasizes the necessity for continuous adaptation and assessment of instructional strategies to meet students' evolving learning needs.

The positive impact of the intervention aligns with previous research demonstrating the efficacy of various teaching strategies. For instance, Lamb and Thanheiser (2006) found that targeted interventions improved students' understanding of mathematics. Similarly, Wang et al. (2012) reported that engagement in recreational activities, such as puzzles, enhanced cognitive skills and performance. Maccini and Ruhi (2000) observed that manipulative, concrete, and abstract instructions significantly improved performance in students with learning disabilities. Dulce

(2017) also found that his experimental model improved mathematics performance. Moreover, Okigbo and Osuafor (2008) highlighted that manipulative effectively enhanced students' performance. Salao (2017) and Torrefranca (2017) noted that diverse teaching approaches and interventions led to improved performance in mathematics. Additionally, Sagcal et al. (2018) and Munger (2007) confirmed that manipulatives contribute to better student skills and mastery. These findings collectively support the conclusion that the intervention used in this study effectively improved students' performance in mathematics.

Table 2. Statistical results in differences in students' performance before and after instruction.

Students' Performance	Mean	SD	Mean Difference	t	df	p
Pretest	4.94	2.49	-4.846	-13.89	1.3	.000
Posttest	9.79	3.67				

Student's Attitude in Operating Integers After Instruction

Students generally exhibited a positive attitude toward operating integers, with a mean score of 4.00. They strongly agreed that working with operations on integers is enjoyable (Mean = 4.49) and expressed a strong willingness to acquire further knowledge in this area (Mean = 4.33). Additionally, they agreed that operations on integers helped them think more clearly (Mean = 4.32). Respondents also strongly agreed (Mean = 4.27) that learning these operations helped develop their minds, solve real problems using common sense, and generate interest in the subject. Their positive attitude towards operating integers was influenced by their perception of the subject as enjoyable, interesting, challenging, and conducive to developing creativity and critical thinking. However, students were uncertain whether operating integers was the most challenging lesson or if it was easily understandable, indicating mixed feelings about the complexity of the topic.

The students' positive attitudes toward operating integers, as reflected in their high mean scores, underscore the findings from previous research on the importance of engaging with mathematical concepts. Their enjoyment of and willingness to delve deeper into operations on integers align with the idea that puzzle-based games and interactive methods enhance problem-solving skills and foster a positive outlook toward mathematics (Bottino et al., 2007; Pentang, 2019). This enthusiasm is consistent with the assertion that concrete examples and manipulatives—tools that can make abstract concepts more tangible—improve understanding and performance (Chang, 2008; Golafshan, 2013). The strong agreement that learning integer operations helps in clear thinking and problem-solving mirrors the research on how effective teaching methods and materials contribute to better academic outcomes (Mbugua et al., 2012; Hjert-Bernardi et al., 2012). Furthermore, the student perceives integer operations as enjoyable and beneficial for developing critical thinking skills. This skill supports the notion that a positive attitude toward math can enhance their willingness to engage with challenging tasks (Salviejo et al., 2024).

The students' positive attitudes towards operating integers highlight the value of engaging and interactive teaching methods in mathematics education. Their enjoyment and interest in learning more about integer operations suggest that puzzle-based games and hands-on exercises enhance problem-solving skills and create a positive learning environment. This supports the idea that using concrete examples and manipulatives helps make abstract concepts more understandable, improving students' performance. The student's belief that learning integer operations aids in clear thinking and problem-solving reinforces the importance of effective teaching strategies in achieving better academic outcomes. However, the varied responses about the complexity of integer operations indicate that while students appreciate the subject, challenges may require additional support.

Table 3. The respondents' attitude in operating integers.

Attitude in Operating Integers	Mean	Level of Agreeableness
Working with operations on integers is enjoyable.	4.49	Strongly Agree
It is encouraging to simplify integers.	4.13	Agree
Operating integers needs a solidarity activity.	4.16	Agree
I try to learn operations on integers because it helps develop my mind.	4.27	Strongly Agree
It helps me think more clearly in general.	4.32	Strongly Agree
I can be able to solve any assigned problem if I understand integers.	3.98	Agree
I have never liked operations on integers.	3.62	Undecided
Operating integers is the most dreaded lesson for me.	3.38	Undecided
I am interested in operating integers.	4.27	Strongly Agree
I am willing to acquire further knowledge in operating integers.	4.33	Strongly Agree
I learn operations on integers well from lectures.	4.00	Agree
In operation on integers, you can be creative.	4.09	Agree
You can discover a technique for operating integers.	4.11	Agree
Integers are not essential in everyday life.	3.38	Undecided
Using puzzles is a good way for me to learn integers.	4.26	Strongly Agree

Real problems in operating integers can be solved by common sense.	4.27	Strongly Agree
Ordinary students cannot expect to understand the operation of integers.	3.24	Undecided
Weighted Mean	**4.00**	**Agree**

Note: 4.21-5.00 (Strongly Agree), 3.41-4.20 (Agree), 2.61-3.40 (Undecided), 1.81-2.60 (Disagree), 1.00-1.80 (Strongly Disagree)

Relationship Between the Students' Performance and Attitude in Operating Integers After Instruction

The study reveals a positive correlation between students' performance and their attitudes toward operating integers ($r = .205$, $p < .05$). This finding suggests that students who perform better in operating integers tend to have more positive attitudes toward the subject following instruction. This relationship indicates that students who excel in this area will likely view the subject more favorably, highlighting the importance of fostering positive attitudes to enhance performance further.

Strengthening students' attitudes towards operating integers can boost their performance, particularly when the learning environment is engaging, collaborative, and free from undue pressure. Research supports this notion: Bacsal et al. (2022) and Samson and Policarpio (2017) demonstrated that cooperative learning environments significantly improve mathematics performance, retention, and problem-solving attitudes. Similarly, Langcauon and Reston (2018) found that activity-based cooperative learning materials foster critical thinking and problem-solving skills and improve students' attitudes toward the subject. Matriano et al. (2017) emphasized the effectiveness of collaborative pre-assessment and formative assessment strategies in enhancing academic performance and attitude development.

Furthermore, Daracco (2017) underscored the significant link between self-concept and mathematics performance, suggesting that students' beliefs about their abilities can influence their performance outcomes. Dela Cruz and Roleda (2018) highlighted the role of interactive games in increasing student interest and enjoyment in subjects. Amada (2018) supported these findings by showing that game-based instruction enhances student engagement across behavioral, emotional, and cognitive domains. These insights collectively reinforce the idea that a positive, engaging, and supportive learning environment can improve students' attitudes and performance in mathematics. Educators can foster a positive attitude towards operating integers and improve student performance by incorporating strategies that enhance enjoyment and collaboration.

Conclusion and Recommendations

Integrating the KenKen puzzle into a collaborative learning environment substantially improved students' performance with integer operations. Initially, students showed low levels of mastery; however, after four days of instruction using the KenKen puzzle, most students advanced toward mastery, with some reaching close to or complete mastery. This significant progress underscores the efficacy of incorporating interactive and engaging interventions like the KenKen puzzle to enhance students' mathematical skills. Additionally, students' attitudes toward integer operations became notably more positive, finding the activity enjoyable, engaging, and beneficial for developing creativity and critical thinking. The positive correlation between performance and attitudes suggests that effective interventions improve mastery and foster a more favorable view of the subject.

To build on these findings, mathematics teachers should consider incorporating innovative instructional materials to address students' strengths and weaknesses. Such methods can make learning more engaging and effective. Professional development opportunities should be pursued to enhance teaching strategies and assessment tools, ensuring educators can implement these innovative techniques. Moreover, fostering a positive attitude toward mathematics is crucial; thus, creating challenging and stimulating activities can support high-performing students and those who find the subject more difficult. Future research should explore how experiential learning theories impact students' performance and attitudes, particularly by considering different learning styles and assessing the long-term effectiveness of various instructional interventions.

Conflict of Interest

The authors declare no conflict of interest.

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Authorship Details

Molina (65%): Concept and design, data acquisition and analysis, writing the manuscript. Ibañez (35%): Data interpretation, supervision, editing the manuscript.

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