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EFFECTIVENESS AND LEARNER ACCEPTABILITY OF SUDOKINTEGERS: A QUASI-EXPERIMENTAL STUDY ON ENHANCING INTEGER OPERATIONS

MARVIN G. BONGATO*,[1] EMMA S. RULONA,[2]
[1]Graduate School and Professional Studies, University of Bohol, Tagbilaran City, Philippines

Corresponding Author:bongatomarvin@gmail.com

ABSTRACT

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Developing computational fluency in integer operations remains a challenge among junior high school learners, highlighting the need for innovative instructional approaches that promote both engagement and conceptual understanding. This study examined the effectiveness and acceptability of Sudokintegers, a game-based instructional material designed to improve Grade 7 students' computational skills in the four operations of integers. A quasi-experimental pretest-posttest design was employed involving control and experimental groups from a public secondary school in the Schools Division of Bohol during the School Year 2024–2025. Students' computational skills were assessed using a validated achievement test, while the acceptability of Sudokintegers was evaluated in terms of satisfaction, usefulness, and ease of use. Descriptive

statistics, paired-samples t-test, Wilcoxon signed-rank test, and Mann–Whitney U test were used to analyze the data. The findings revealed that students perceived Sudokintegers as highly acceptable across all dimensions. Although both groups demonstrated significant improvement, learners exposed to Sudokintegers achieved significantly higher posttest performance than those who received traditional instruction. The results suggest that integrating game-based instructional materials into mathematics teaching can strengthen computational fluency while enhancing learner engagement and motivation. The study supports the use of contextualized educational games as complementary instructional resources for improving mathematics learning in the junior high school curriculum. Teaching can strengthen computational fluency while enhancing learner engagement and motivation. The study supports the use of contextualized educational games as complementary instructional resources for improving mathematics learning in the junior high school curriculum. Public organizations increasingly recognize that employees' psychological resources contribute significantly to organizational effectiveness and the delivery of quality public services. This study examined the adversity quotient, grit, and service quality of employees of the Provincial Government of Bohol and explored the relationships among these constructs. Employing a quantitative descriptive-correlational design, data were collected from 330 regular employees selected through simple random sampling using the Adversity Response Profile (ARP®), the Short Grit Scale (Grit-S), and an adapted SERVQUAL instrument. Descriptive statistics and Kendall's Tau-b correlation analysis were utilized to analyze the data. Findings revealed that respondents demonstrated an above-average adversity quotient ($M = 3.44$), characterized by stronger perceptions of control and ownership in the face of workplace challenges. Employees likewise exhibited high levels of grit, with perseverance of effort emerging as the dominant characteristic ($M = 3.92$), and perceived the service quality as highly satisfactory ($M = 4.18$), particularly in terms of empathy and assurance. Correlation analysis showed that adversity quotient was positively associated with grit ($\tau b = .134$, $p < .001$) and service quality ($\tau b = .105$, $p = .006$), while grit exhibited a stronger positive association with service quality ($\tau b = .261$, $p = .006$). Although the relationships were modest, the findings suggest that resilience and perseverance function as complementary psychological resources that support effective public service delivery and organizational performance.

INTRODUCTION

Math skills development remains a top priority in education because they are needed for logical thinking, problem-solving, and making smart choices across all subjects and in everyday life. It is especially important to understand basic math ideas in the first few years of secondary school, when students are moving from basic math to more complex mathematical thinking.

Integer operations are one of these basic skills that you need to know before you can move on to algebra, geometry, and higher-level math. Still, many students have persistent misunderstandings when working with positive and negative integers, which lead to problems that carry over into more complex mathematical ideas (Alfarisi, 2022; Nurnberger-Haag et al., 2022). These problems are still being brought up in international reviews. The Program for International Student Assessment (PISA) 2022 showed that math achievement is still below the international average in many school systems, including the Philippines. In this country, only a small percentage of students reached the minimum level of proficiency needed for meaningful mathematical reasoning (OECD, 202`). These results show how important it is to continue using teaching methods that go beyond simple computation and involve students in building their mathematical understanding.

In basic education in the Philippines, the MATATAG Curriculum focuses on building foundational skills, understanding big ideas, and getting back on track after learning loss. These changes give math teachers the chance to use new teaching methods that engage students and help them learn in meaningful ways. Learner-centered approaches that support discovery, collaboration, and problem-solving rather than passively receiving knowledge are becoming more popular in modern mathematics education (Boaler, 2022). Educational games have become one of the most promising ways to teach because they keep students engaged and help them understand concepts more effectively. More and more people are interested in game-based learning because it blends fun learning with mental challenges. Educational games give quick feedback, support repeated practice, and create safe spaces where students can try out math ideas without feeling too stressed. There is meta-analytic evidence that well-designed game-based treatments can improve students' math skills, motivation, and engagement, especially when used as part of classroom instruction rather than as separate activities (Tokac et al., 2019; Wamg et al.,2022)

Sudoku is a game that is good for education because it helps kids learn to think logically, recognize patterns, and plan. As a reasoning game, Sudoku has been extensively studied. However, fewer studies have examined variations that deliberately include math-education skills, especially integer operations. Based on these ideas, Sudokintegers was created as a contextualized learning tool that blends the logical structure of Sudoku with computing tasks involving the four basic operations on integers. In an interesting, puzzle-based learning setting, the material offers students many opportunities to apply mathematical ideas. Even though most studies on game-based math education have found positive results, there is still not much real-world evidence for Sudoku-inspired materials for teaching integer operations. Also, a few quasi-experimental studies have examined how well these tools teach and how well students like them in Philippine secondary schools that use the MATATAG program. Filling this gap could contribute to the growing body of evidence supporting

new teaching materials that improve math skills and more effectively engage students.

Drawing on this point of view, this study examined how well Sudoku helps 7th graders improve their use of the four operations in math. It looked at how satisfied, useful, and easy to use users found it. The results should help math education by demonstrating the usefulness of game-based learning tools in supporting classroom teaching and improving basic math skills.

THEORETICAL BACKGROUND

The current study is based on three theories: Constructivist Learning Theory, Flow Theory, and Self-Determination Theory. These theories explain how meaningful involvement, active knowledge-building, and natural motivation help students learn math through game-based instruction.

The theory of constructivism in learning. The constructivist learning theory, largely attributed to Jean Piaget in 1972, holds that people build their knowledge by connecting new events to what they already know. Students do not passively take in knowledge; they build conceptual understanding by exploring, thinking about, and solving problems. In math class, constructivist teaching encourages students to make connections among mathematical ideas and to develop conceptual understanding rather than just memorizing steps. Educational games let you explore concepts over and over, helping students improve their thinking while providing instant feedback. As a result, puzzle-based learning materials like Sudoku integers may help students gain a better understanding of integer operations by making mathematical concepts more concrete through real-life problem-solving.

The flow theory. Csikszentmihalyi (1990) developed the Flow Theory, which holds that people learn best when they are fully engaged in tasks that strike the right balance between challenge and ease. Learners can stay focused, enjoy what they are doing, and be internally motivated when they are in a state of flow. This allows them to keep going even when the tasks are hard. Math games often have these traits by giving players tasks that get harder over time, giving them instant feedback, and making their goals clear. When students feel in the flow during math class, they are more likely to persist with challenging problems, which improves both their engagement and their success.

The theory of self-determination. Self-Determination Theory (Ryan & Deci, 2020) says that learners become intrinsically motivated when they feel independent, competent, and connected. Setting up schools where students can make important decisions, succeed, and work with others encourages greater participation and better learning. Game-based learning tools easily meet these psychological needs by allowing students to explore on their own, setting achievable challenges, and enabling them to work together to learn. Because of this, students are more likely to work hard and stay motivated during the learning process if they find the tools fun and useful.

Taken together, these theoretical approaches provide a full picture of how Sudoku might affect learning math. Constructivism says that active problem-solving helps students understand abstract ideas. Flow Theory says that interesting game features help people stay focused and keep going. Self-determination Theory says that fun learning experiences help people stay motivated and continue participating. Putting these theories together suggests that adding logical questions to math lessons might help students improve their computational skills while also making them more interested in, motivated by, and positive about math.

REVIEW OF RELATED LITERATURE

Game-Based Learning in Mathematics Education. More and more people are realizing that game-based learning is an effective way to help students learn math. In contrast to standard teacher-centered lessons, educational games encourage students to build their knowledge by exploring, actively participating, receiving instant feedback, and solving problems repeatedly. If you create mathematical games that are both challenging and fun, they will encourage students to keep going, reduce their fear of math, and become more engaged with the subject. A review of the research shows that learning through games can slightly improve math skills. This is especially true when educational games are used in the classroom to help students reach specific learning goals (Tokac et al., 2019; Wang et al., 2022). From these results, it looks like games work best when used alongside proven teaching methods, not instead of them.

In addition to helping students perform better in school, game-based learning promotes teamwork, strategic thinking, and independence. Students take an active role in the learning process by generating answers, reviewing strategies, and reflecting on their mistakes. This helps them understand concepts better and think more mathematically. These kinds of learner-centered experiences align with changes in math education that emphasize questioning, problem-solving, and higher-order thinking.

Computational Fluency in Integer Operations. Computational fluency in integer operations forms an essential foundation for learning algebra and advanced mathematics. Students who have difficulty with positive and negative numbers often hold persistent misconceptions that hinder later mathematical learning. Research consistently shows that learners frequently rely on memorized procedures without fully understanding the underlying concepts governing integer operations. These misconceptions contribute to computational errors and reduced confidence in solving mathematical problems (Nürnberger-Haag et al., 2022).

Current mathematics education literature advocates instructional strategies that integrate conceptual understanding with procedural fluency. Rather than relying solely on repetitive drill, teachers are encouraged to provide

learning experiences that allow students to explore patterns, justify solutions, and connect abstract concepts to meaningful representations. Interactive games and mathematical puzzles provide opportunities for repeated practice while maintaining learner motivation and engagement.

Sudoku as a Mathematical Learning Tool. Sudoku is widely recognized as a logic-based puzzle that develops reasoning, pattern recognition, concentration, and deductive thinking. Although originally designed for recreational purposes, Sudoku has attracted educational interest because solving puzzles requires systematic analysis, strategic planning, and logical decision-making. These cognitive processes closely parallel mathematical reasoning and problem-solving. Recreational mathematics scholars have likewise argued that Sudoku offers learners opportunities to appreciate mathematical structures beyond routine computation, particularly through logical deduction rather than trial and error.

Building upon these characteristics, educators have begun adapting Sudoku principles into curriculum-based instructional materials. Instead of using conventional digits alone, modified Sudoku activities incorporate mathematical operations, algebraic expressions, or number relationships aligned with specific learning competencies. Such adaptations maintain the motivational appeal of puzzles while simultaneously reinforcing curricular content.

Learner Satisfaction and Instructional Acceptability. The effectiveness of instructional innovations extends beyond academic performance and includes learners' perceptions of usability, engagement, and satisfaction. According to Self-Determination Theory, instructional materials perceived as enjoyable and useful are more likely to foster intrinsic motivation, sustained participation, and meaningful learning (Ryan & Deci, 2020). Similarly, educational technology research suggests that perceived usefulness and ease of use influence learners' willingness to adopt innovative instructional materials.

Studies on educational games consistently report positive learner perceptions when games provide clear objectives, appropriate levels of challenge, immediate feedback, and opportunities for independent learning. High levels of learner satisfaction, therefore, strengthen the sustainability of instructional innovations and encourage continued classroom implementation.

REVIEW OF RELATED STUDIES

An international study generally supports the idea that learning math through games is an effective way to teach. An in-depth meta-analysis by Tokac et al. (2019) found that using games to teach math had a significant positive impact on students' math performance, especially when games were incorporated into regular classroom lessons rather than used as extra activities. Also, Wang et al. (2022) reported that digital game-based learning improved math achievement and pupil engagement across a variety of educational

settings.

In recent years, people have also looked into designing math games that help kids understand concepts rather than memorize steps. Lozano et al. (2023) developed a mobile app for learning mathematical patterns and structures built around games. They said that both students and IT experts gave the games positive reviews, suggesting that well-designed mathematical games may keep students interested and help them learn.

Most research on Sudoku has examined its potential to support problem-solving, rational thought, and deductive reasoning. Mathematicians say that Sudoku is an ordered, logical system similar to Latin squares, graph coloring, and combinatorial reasoning. This shows that it can help you think more deeply about problems rather than just practicing math. These features make Sudoku a good teaching tool, but few real-world studies have examined variations that teach specific math concepts, such as number operations taught in school.

In the Philippines, more and more research on math teaching has examined how contextualized learning tools, manipulatives-based instruction, and game-assisted learning can help students perform better and become more interested in learning. However, most of the studies conducted so far have focused on general math skills or digital teaching games. There is little evidence for puzzle-based learning materials specifically designed to help junior high school students compute integer operations more quickly.

Not only that, but earlier studies have mostly looked at how well students did in school, not much at how they thought about the acceptability, usefulness, and usability of the teaching tools. It is important to understand these aspects because the extent to which students accept new ways of teaching affects how they are used in the classroom and how long they last.

All of this research shows that educational games can help students learn math by increasing their drive and interest. However, there is still not much real-world data on Sudoku-inspired teaching tools that clearly incorporate the four operations of numbers in the junior high school curriculum in the Philippines. Also, a few quasi-experimental studies have examined both how well teaching works and how well students accept it simultaneously. These gaps led to this study, which examines how well Sudoku works as a creative way to teach 7th graders math and how happy the students are with it.

METHODOLOGY

Research Design. This study employed a **quasi-experimental one-group pretest-posttest design** to evaluate the effectiveness of **Sudokintegers**, a game-based instructional material, in improving Grade 7 students' computational skills in the four operations of integers. The design enabled the comparison of students' performance before and after the intervention in an intact classroom where random assignment was not feasible (Creswell & Creswell, 2018).

Research Participants and Setting. The study was conducted in a public secondary school in the **Schools Division of Bohol, Philippines**, during the School Year 2024–2025. Participants were Grade 7 students selected through purposive sampling based on their enrollment in the participating class and completion of the instructional unit on integer operations.

Research Instruments. The intervention utilized **Sudokintegers**, a researcher-developed instructional material that integrates Sudoku puzzle mechanics with computational exercises involving addition, subtraction, multiplication, and division of integers. The material was validated by experts in mathematics education and curriculum development prior to implementation. Students' computational skills were measured using a **40-item researcher-developed achievement test** aligned with the Grade 7 Mathematics competencies under the MATATAG Curriculum. Learners' perceptions of the instructional material were assessed using a validated questionnaire covering four dimensions: **objectives, content, usefulness, and ease of use**, rated on a five-point Likert scale. Both instruments demonstrated acceptable content validity and reliability (Cronbach's $\alpha \geq .70$).

Data Collection Procedures. Following approval from the school administration, students completed the pretest before Sudoku was introduced during regular mathematics lessons on integer operations. After the intervention, participants completed the posttest and the acceptability questionnaire under standardized classroom conditions.

Statistical Analysis. Descriptive statistics (frequencies, percentages, means, and standard deviations) were used to summarize students' computational performance and perceptions of the instructional material; the Shapiro–Wilk test assessed the normality of the data. Depending on the results, either the **paired-samples *t*-test** or the **Wilcoxon signed-rank test** was employed to determine significant differences between pretest and posttest scores at the 0.05 level of significance. Statistical analyses were performed using IBM SPSS Statistics.

Ethical Considerations. Permission to conduct the study was obtained from the appropriate school authorities. Participation was voluntary, and informed consent from parents or guardians and student assent were secured before data collection. Confidentiality and anonymity were maintained throughout the study in compliance with the Philippine Data Privacy Act of 2012 (Republic Act No. 10173).

RESULTS AND DISCUSSION

Table 1 summarizes students' evaluation of Sudokintegers across the three dimensions of instructional acceptability. Overall, the instructional material received a Strongly Agree rating ($M = 3.378$), indicating that learners perceived it as enjoyable, useful, and easy to use.

Table 1. *Overall Acceptability of Sudokintegers*

Dimension	Median	IQR	Mean	Interpretation
Satisfaction	3.00	1.00	3.398	Strongly Agree
Usefulness	3.00	1.00	3.395	Strongly Agree
Ease of Use	3.00	1.00	3.323	Strongly Agree
Overall	**3.00**	**1.00**	**3.378**	**Strongly Agree**

Note. Median interpretation: 1 = Strongly Disagree; 2 = Disagree; 3 = Agree; 4 = Strongly Agree. Mean interpretation: 3.25–4.00 = Strongly Agree; 2.50–3.24 = Agree.

Consistent median and IQR values further suggest that students shared relatively similar perceptions of the intervention. These findings imply that Sudokintegers created a positive learning environment that encouraged active participation while reducing the perceived difficulty of learning integer operations. The results support what other research has found: using game-based learning materials in math class makes students more interested, happier, and more likely to perceive the materials as useful (Tokac et al., 2019; Wang et al., 2022). The results also support Self-Determination Theory, which posits that learning that is both fun and important increases intrinsic motivation and long-term interest (Ryan & Deci, 2020).

There were two tests: one before the experiment and one after. The results are shown in Table 2. The average performance for both groups was about the same, with very low pretest scores showing that they were both pretty good at computing before the intervention.

Table 2. *Pretest and Posttest Performance of the Control and Experimental Groups*

Group	Pretest Mean (SD)	Description	Posttest Mean (SD)	Description	Gain
Control	16.27 (6.07)	Very Low	35.68 (22.25)	Low	+19.41
Experimental	16.41 (5.95)	Very Low	49.45 (24.95)	High	+33.04

Note. *Higher scores indicate better computational proficiency in integer operations.*

Following instruction, both groups improved; however, students who used **Sudokintegers** achieved substantially higher posttest scores and greater learning gains than those who received traditional instruction. They scored 19.41 points higher than the control group, for a total of 33.04 points. This means that playing games to learn math may have helped speed up computation more than other teaching methods. Students do better in math when they play educational games because they are more interested, practice more, and better understand what they are learning (Tokac et al., 2019; Wang et al., 2022). The results also align with Flow Theory, which holds that activities that are just the right amount of hard keep students' attention and motivation, helping them learn more (Csikszentmihalyi, 1990).

How well did the students do on the four computer skills after taking the test? Look at Table 3. There was no area in which the experimental group performed worse than the control group in number operations. When students played Sudoku, they did better than the control group, who performed poorly. This was the biggest help.

Table 3. *Posttest Performance by Computational Skill*

Skill	Control Median	Description	Experimental Median	Description
Addition	3.50	Low	16.00	High
Subtraction	6.00	Very Low	10.00	Low
Multiplication	10.00	High	13.50	Very High
Division	8.50	High	13.00	Very High

Note. *Median scores are reported because the distributions were non-normal.*

Even though both groups still found subtraction to be the hardest skill, the students who played Sudoku with integers did better overall. The experimental group also performed very well in both multiplication and division, suggesting that the teaching materials effectively improved basic speed across multiple computing areas. These results show that the puzzle-like structure of Sudoku made it easier to apply mathematical ideas repeatedly while keeping students interested. Researchers have found that teaching math through games improves students' ability to compute, think logically, and do well in math (Juandi et al., 2021; Wang et al., 2022; Tokac et al., 2019).

Significant Difference Between the Pretest and Posttest Scores of the Control Group. There was a statistically significant improvement in the computer skills of students who received standard training ($t = -4.569$, $p < .001$). The control group did better than the experimental group, but that is mostly because direct teaching, led practice, and repeated tasks worked well at improving procedural speed in integer operations.

Table 4. *Significant Difference Between the Pretest and Posttest Scores of the Control Group*

Test	Mean	*t*-value	*p*-value	Decision	Interpretation
Pretest	16.27	-4.569	< .001	Reject H_0	Significant
Posttest	35.68				

Note. Paired-samples *t*-test comparing pretest and posttest scores after traditional instruction.

Alfarisi (2022) found similar findings. He said that traditional math teaching can help students improve at computing, but students may still have trouble with integers without more hands-on learning experiences. The results show that standard teaching remains helpful, but there are greater opportunities to improve students' conceptual learning by using new teaching

methods.

Significant Difference Between the Pretest and Posttest Scores of the Experimental Group. In Table 5, you can see that the experimental group did significantly better after playing Sudoku ($Z = -3.921$, $p < .001$). It is clear from the large jump in median scores that the assistance really helped students improve at computing with integer operations.

Table 5. *Significant Difference Between the Pretest and Posttest Scores of the Experimental Group*

Test	Median	*Z*-value	*p*-value	Decision	Interpretation
Pretest	17.50	-3.921	< .001	Reject H_0	Significant
Posttest	47.00				

Note. Wilcoxon signed-rank test comparing pretest and posttest scores after the Sudoku intervention.

The puzzle-based structure of Sudoku likely promoted repeated practice, logical reasoning, and sustained learner engagement, thereby supporting both procedural fluency and conceptual understanding. These findings are consistent with studies reporting that game-based mathematics instruction enhances learner achievement by fostering active participation and meaningful problem-solving (Hidayat et al., 2024; Jaramillo-Mediavilla et al., 2024). The results likewise support **Constructivist Learning Theory** and **Flow Theory**, which propose that active exploration and appropriately challenging learning experiences facilitate deeper mathematical learning.

Difference Between the Posttest Scores of the Control and Experimental Groups. There was a statistically significant difference in post-test scores between the experimental and control groups ($U = 158.50$, $p = .050$), with the experimental group having higher mean ranks than the control group. This result shows that teaching math with Sudokintegers led to bigger improvements in students' computer skills than just teaching math the old way.

Table 6. *Difference Between the Posttest Scores of the Control and Experimental Groups*

Group	Mean Rank	Mann–Whitney *U*	*p*-value	Decision	Interpretation
Experimental	26.30	158.50	.050	Reject H_0	Significant
Control	18.70				

Note. Mann–Whitney *U* test comparing posttest scores of the control and experimental groups.

The result supports previous research demonstrating that game-based instructional approaches enhance mathematics achievement by increasing learner engagement, providing immediate feedback, and encouraging repeated

application of mathematical concepts (Karamert & Kuyumcu Vardar, 2021; Tokac et al., 2019; Wang et al., 2022). Collectively, the findings provide empirical support for the instructional effectiveness of Sudokintegers as an innovative learning resource for teaching integer operations among Grade 7 learners.

CONCLUSION

The results show that both standard lessons and Sudoku grids helped students improve at using computers to perform integer operations. Children who took part in the Sudokintegers intervention, on the other hand, learned more and did much better on tests afterward than children who received only regular instruction. Students also thought the teaching materials were very good, helpful, and easy to use, suggesting that the game-like format worked well to keep them interested and help them learn. These results show that Sudokintegers could be used as an additional tool to support teaching, as they improve procedural skills and promote rational thinking, active involvement, and long-term motivation. Even though traditional teaching is still a good way to learn basic math skills, incorporating structured educational games may give students more opportunities to deepen their understanding of concepts through fun, engaging activities. In general, the study shows that using game-based learning tools in math classes can help students get better at handling integer functions.

RECOMMENDATIONS

Based on the findings of the study, the following recommendations are offered:

1. **Mathematics teachers** may integrate Sudoku and similar game-based instructional materials into lessons on integer operations to reinforce computational fluency, learner engagement, and conceptual understanding.
2. **School administrators** may support the development and classroom utilization of innovative mathematics instructional materials through professional development activities and instructional resource programs.
3. **Curriculum developers** may consider incorporating structured game-based learning activities into mathematics modules and learning resources to complement conventional instructional strategies.
4. **The Department of Education** may encourage the development, validation, and dissemination of contextualized instructional games that support the objectives of the MATATAG Curriculum and mathematics learning recovery initiatives.
5. **Future researchers** may replicate the study using larger and more

diverse samples, other mathematical competencies, or longitudinal and mixed-methods designs to examine further the long-term effectiveness of Sudokintegers and related game-based instructional interventions.

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