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Development of an Interactive Board Game in Solving Integer Word Problems Using the Strategic Integers' Cubes Mastery (SICM) Approach

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Abstract

This study aimed to design, develop, and evaluate Strategic Integers' Cubes Mastery (SICM), an interactive board game created to enhance Grade 7 students' proficiency in solving algebraic word problems involving integers. Rooted in the principles of Realistic Mathematics Education (RME), the study sought to integrate mathematical understanding with interactive, student-centered learning experiences. Employing a descriptive-developmental research design guided by the ADDIE model, the study was conducted at Talavera National High School with 56 student participants. Expert validators and user feedback assessed the SICM board game's content, design, functionality, and pedagogical

soundness. Results revealed a significant improvement in students' performance, with pre-test ($M = 12.03$) and post-test ($M = 19.08$) scores yielding $t = 25.00$ and $p < 0.00$, confirming the game's effectiveness. Experts rated the game "very good" across all evaluation criteria, while teachers and students found it highly useful and engaging for instruction and learning. Overall, the findings affirm that the SICM board game is a valid, pedagogically sound, and effective tool that promotes mathematical understanding, motivation, and problem-solving skills through interactive and enjoyable gameplay.

Keywords: Game-Based Learning, Algebra Word Problems, Integer Operations, Board Game, SICM

1. Introduction

1.1 Context and Rationale

Algebraic word problems involving integers are an important concept in mathematics, particularly within the high school curriculum. Integers form a foundational concept in arithmetic and algebra, serving as a prerequisite for higher mathematical reasoning. However, many students struggle with misconceptions, especially in operations involving negative integers (Nur *et al.*, 2022) ^[10]. As Ling *et al.* (2017) ^[8] emphasized, solving algebraic word problems requires executing a sequence of arithmetic operations, demanding both procedural fluency and conceptual understanding. Proficiency in integer operations is, therefore, essential for developing logical reasoning and analytical thinking, which are vital for advanced mathematical learning.

To address persistent learning challenges, game-based learning (GBL) has emerged as an effective pedagogical approach. Pho & Dinscore (2015) ^[13] described GBL as the integration of gaming principles into instructional contexts to promote engagement and active learning. Unlike traditional instruction, GBL encourages exploration and enjoyment while guiding learners toward achieving specific learning outcomes. Supporting this notion, Boffending & Hoffman (2014) ^[3] found that students who engaged in board game activities showed significant improvements in recognizing and ordering integers.

Building on these insights, the Strategic Integers' Cubes Mastery (SICM) was developed as an innovative, interactive board game designed to strengthen students' mastery of integer-based algebraic word problems. Rooted in game-based learning and cognitive development principles, SICM aims to foster deeper understanding and sustained engagement through hands-on, collaborative play.

Although numerous studies have examined the impact of educational games in mathematics, limited research has explored the design and development of interactive board games specifically targeting integer learning. Addressing this gap, the present study seeks to design, develop, and evaluate the effectiveness of the Strategic Integers' Cubes Mastery (SICM) in enhancing students' conceptual understanding and problem-solving performance in algebraic word problems involving integers.

1.2 Literature Review

Challenges in Learning Algebra Word Problems

Integers are fundamental in developing students' understanding of arithmetic and algebra, yet misconceptions persist in performing integer operations. Students frequently struggle with algebraic word problems involving integers due to misconceptions and limited conceptual understanding. Nur *et al.* (2022) ^[10] reported that learners demonstrated only near mastery of integer operations, particularly with subtraction and negative numbers, which hindered their ability to solve algebraic problems. Owusu (2023) and Sultan (2014) ^[15] further noted that difficulties often stem from weak prerequisite skills, misinterpretation of symbols, and challenges in translating verbal statements into mathematical expressions. Amador (2022) ^[1] emphasized that poor reading comprehension and negative attitudes toward mathematics exacerbate these issues, underscoring the need for innovative, engaging strategies to enhance problem-solving and conceptual understanding.

Game-Based Learning in Mathematics Education

Game-based learning (GBL) has gained significant traction for its capacity to increase engagement and achievement in mathematics. Vankuš (2021) ^[17] found that most GBL studies reported improvements in motivation, enjoyment, and sustained focus, with 84% showing positive affective outcomes. Similarly, Cayang & Ursabia (2024) ^[4] found that mathematics instruction incorporating game-based strategies yielded higher academic performance than conventional approaches. Their work underscored the need to redesign instructional materials to align gaming mechanics with learning objectives. Collectively, the evidence supports the claim that GBL transforms abstract mathematical concepts into meaningful experiences, cultivating not only academic proficiency but also positive dispositions toward mathematics learning.

Principles of Effective Game Design

Effective educational game design requires harmonizing gameplay mechanics with instructional objectives. Czuderna & Guardiola (2019) ^[5] identified key shortcomings in many designs, including the separation of learning and play and the neglect of gameplay dynamics in knowledge acquisition. Their research advocated for an integrated framework where play becomes an essential mode of learning. Similarly, Udjaja *et al.* (2018) ^[16] demonstrated that expert-system-based games simplify mathematical concepts and enhance student interactivity. Well-structured games thus act as pedagogical bridges, translating abstract content into experiential learning. Aligning mechanics, motivation, and assessment ensures that educational games achieve both engagement and measurable academic outcomes.

Studies on Algebra Learning and Board Games

Research integrating board games and technology has shown strong potential to enhance algebra learning. Zabala-Vargas *et al.* (2021) ^[18] found that digital board games improved both cognitive and affective learning outcomes, boosting comprehension and motivation. Hwang *et al.* (2016) ^[6] confirmed similar gains in algebraic reasoning within digital game-based environments. Assapun and Thummaphan (2023) ^[2] reported that strategic play improved creative problem-solving and decision-making

skills, while O'Neill & Holmes (2022) ^[11] demonstrated the broader developmental benefits of board games in cognitive and social-emotional domains. These findings underscore the pedagogical value of integrating board games into mathematics instruction to cultivate engagement, critical thinking, and deeper conceptual understanding.

2. Materials and Methods

2.1 Research Design

This study employed a quantitative descriptive-developmental research design guided by the ADDIE Model (Analysis, Design, Development, Implementation, and Evaluation) to ensure a systematic and iterative process in creating and validating the board game. This approach enabled systematic development, data-driven refinement, and assessment of learning outcomes, ensuring that the instructional tool effectively enhanced students' understanding and engagement in mathematics (Ibrahim, 2016) ^[7].

2.2 Respondents of the Study

The study employed purposive sampling to select 56 participants relevant to the research objectives. These included 40 Grade 7 students, 10 mathematics teachers, 3 instructional materials experts, and 3 mathematics experts. Selection was based on teaching experience, academic qualifications, and subject expertise. This approach ensured a credible and diverse pool of evaluators, providing comprehensive insights into the effectiveness of the Strategic Integers' Cubes Mastery (SICM).

2.3 Research Instrument

To collect data and evaluate the board game, the researchers utilized the following instruments:

- Expert Validator's Instrument – Administered to mathematics experts and instructional material experts to assess the validity and suitability of SICM in achieving its instructional goals.
- Achievement Test Instrument – Administered to Grade 7 students to measure knowledge and skills in integer operations, determining whether SICM improved problem-solving performance.
- Student Evaluation Checklist – Used to assess students' comprehension and application of integer concepts after playing the board game.
- Teacher Evaluation Checklist – Used to evaluate how effectively teachers facilitated instruction with SICM and to identify strengths and areas for improvement.

Together, these instruments ensured a systematic evaluation of SICM's instructional value.

2.4 Research Procedure

The study followed the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation).

- Analysis Phase – Surveys were administered to mathematics teachers to identify essential competencies, learning difficulties, and specific gaps in solving integer word problems.
- Design Phase – The game's mechanics, aesthetics, and engagement features were conceptualized, and teachers, experts, and students evaluated early prototypes.
- Development Phase – The board game's content, problem cards, and visual components were developed and refined through iterative revisions based on small-

group testing and expert feedback.

- d. **Implementation Phase** – A pilot test was conducted with Grade 7 students, and pre-tests and post-tests were administered to assess improvements in problem-solving performance.
- e. **Evaluation Phase** – The game was validated by experts and evaluated by teachers and students on content quality, design, functionality, and instructional effectiveness.

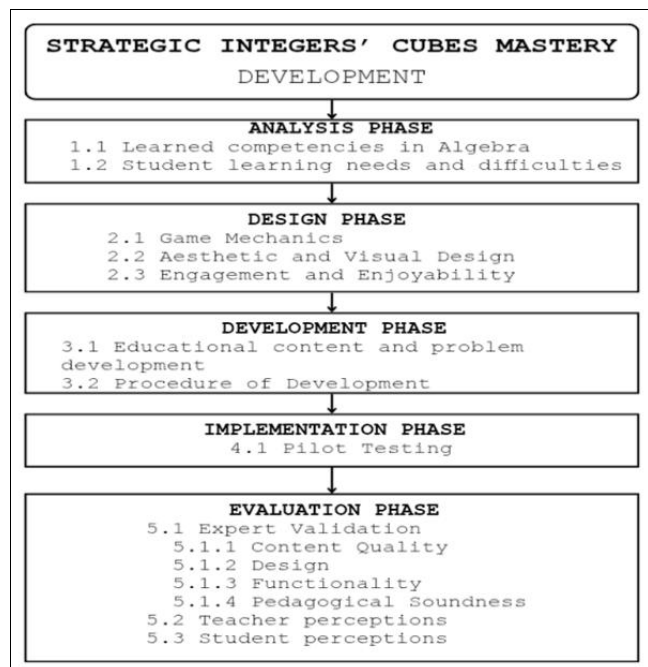


Fig 1: Procedure for Developing Strategic Integers' Cubes Mastery (SICM)

3. Results and Discussion

3.1 Analysis

Determine the Learned Competencies in Algebra and Identify Students' Learning Needs and Difficulties

In this phase, the researchers examined the learned competencies in Algebra as outlined in the Grade 7 MATATAG Curriculum Guide, with a particular focus on the four fundamental operations on integers, as integrated into word problems, within the Quarter 3 learning competencies. This stage aimed to determine the specific areas where students encounter challenges in understanding and applying these concepts. To supplement the document analysis, surveys were administered to two Grade 7 Mathematics teachers at Talavera National High School. Both teachers consistently identified subtraction involving integers as the most difficult competency for students, particularly when presented in word problem form. They emphasized that students often struggle with reading comprehension and problem analysis, which leads to errors in identifying the correct operations to use. For instance, students often confuse addition, subtraction, and multiplication when translating word problems into mathematical equations. These findings revealed that comprehension and analytical reasoning were the primary barriers to mastering word problems involving integers.

3.2 Design

Describe the design of the board game in terms of its game mechanics, aesthetic and visual design, and the level of

engagement and enjoyment.

Game Mechanics

The design phase focused on developing an engaging board game that integrated mathematical reasoning with interactive gameplay to enhance students' ability to solve integer word problems. In Strategic Integers' Cubes Mastery (SICM), students formed two groups of five. Each player drew a word problem from a mystery box and had two minutes to solve it. Correct answers allowed a dice roll to determine movement along the board, which features vines and monkey checkpoints, adding strategic twists. The game concluded when a group reached the top or advanced the furthest within 15 minutes, merging learning with enjoyment and collaboration.

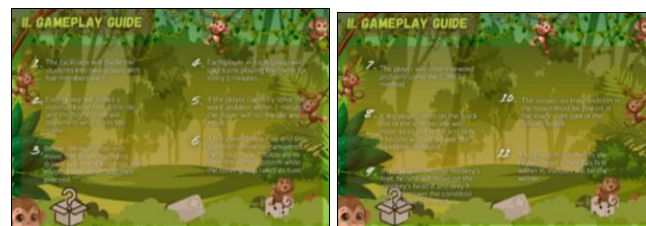


Fig 2: Gameplay Guide

Aesthetic and Visual Design

The aesthetic and visual design of Strategic Integers' Cubes Mastery (SICM) adopted a vibrant jungle theme featuring monkeys, vines, ladders, and colorful paths to capture learners' attention and sustain engagement. Inspired by Snakes and Ladders, the design replaced snakes with monkeys and vines to create a friendly and motivating atmosphere. Warm greens and earthy tones enhanced immersion, while numbered paths ensured clarity in gameplay. Additional elements such as treasure boxes, dice, and cards heightened excitement and reinforced learning objectives. Overall, the design effectively combined visual appeal and functionality to create an engaging and enjoyable educational experience.



Fig 3: Board Game Design

Engagement and Enjoyability

Drawing inspiration from Snakes and Ladders, the Strategic Integers' Cubes Mastery (SICM) board game introduces an interactive twist. Before moving along the board, players must correctly answer a math question involving integers. Correct answers allow players to climb "monkey power-ups" or avoid "vine power-downs," transforming chance-based play into an active learning experience. This mechanic links progress to problem-solving ability, fostering

engagement, confidence, and motivation. Visual cues, movement, and friendly competition encourage persistence and reduce anxiety. By blending educational content with game dynamics, SICM creates an enjoyable, meaningful, and cognitively stimulating environment that supports mathematical learning and collaboration.



Fig 4: Board Game Features

3.3 Development

Educational Content and Problem Development

In developing the Strategic Integers' Cubes Mastery (SICM) board game, researchers applied insights from the analysis phase to address students' difficulties with integer-based word problems. The educational content was contextualized in real-life scenarios requiring integer operations to promote critical thinking and problem-solving. Word problems were carefully designed and categorized by difficulty to accommodate varying learner abilities. These problems were seamlessly integrated into the gameplay mechanics, making problem-solving a prerequisite for progression. This intentional design ensured that cognitive engagement and mathematical reasoning were central to the learning experience, effectively blending instructional goals with interactive and enjoyable gameplay.

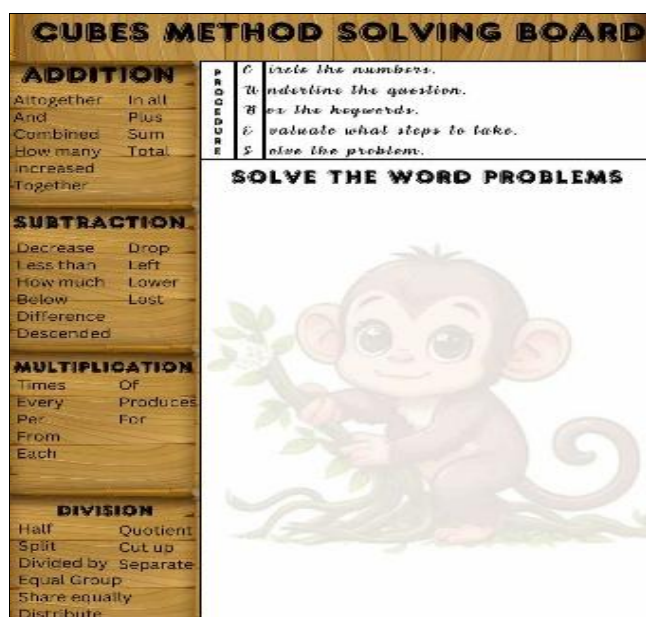


Fig 5: CUBES Method Solving Board

Procedure of Development

The final version of the Strategic Integers' Cubes Mastery (SICM) board game was developed with precision,

integrating engaging visuals, a clear layout, and key educational components. The research team designed and refined essential elements, including dice, problem cards, and gameplay rules, to ensure coherence between learning objectives and enjoyment. Multiple playtests were conducted to validate rule clarity, mechanical balance, and player engagement. Feedback from these sessions guided iterative refinements, resulting in a well-balanced, interactive learning tool. After completion, the game underwent teacher evaluation and was approved as an effective instructional aid for teaching integer-based word problems.



Fig 6: Dice and Problem Cards

3.4 Implementation

Pilot Implementation

Table 1: Difference in the Academic Achievement after SICM Board Game

Group	Mean	SD	t-value	p-value	Verbal Description
Pre-Test	12.03	4.16	25.00	0.000	Significant
Post-Test	19.08	2.91			

During the implementation phase, the Strategic Integers' Cubes Mastery (SICM) board game was pilot-tested among Grade 7 Makabansa students at Talavera National High School. Prior to gameplay, students were oriented on the procedures and rules of the board game. The researchers, together with the mathematics teacher, observed the activity to monitor engagement and comprehension. A pre-test and post-test were administered to measure learning gains. Results showed a significant improvement from a mean pre-test score of 12.03 ($SD = 4.16$) to a post-test score of 19.08 ($SD = 2.91$), with $t = 25.00$ and $p = .000$. This indicates that SICM effectively enhanced students' understanding and problem-solving skills in integer-based word problems.

3.5 Evaluation

Expert Validation

Table 2: Expert Evaluation of SICM Board Game

Criteria	Teachers	VD	Math Experts	VD	IM's Experts	VD
Design	3.79	Very Good	3.77	Very Good	3.87	Very Good
Content Quality	3.76	Very Good	3.77	Very Good		
Functionality	3.75	Very Good	3.83	Very Good		
Pedagogical Soundness	3.73	Very Good	4.00	Very Good		

Table 2 presents the expert evaluation of the Strategic Integers' Cubes Mastery (SICM) board game across four criteria -content quality, design, functionality, and

pedagogical soundness —assessed by mathematics teachers, mathematics experts, and instructional materials experts. Results indicate consistently high ratings, with all evaluators categorizing the board game as very good. Mathematics teachers rated the content quality ($M = 3.76$) and design ($M = 3.79$) highly, recognizing the material's alignment with Grade 7 algebra competencies and its potential to address learners' difficulties with integer-based word problems. Mathematics experts gave the highest rating for pedagogical soundness ($M = 4.00$), reflecting the game's strong instructional foundation and its integration of conceptual understanding with problem-solving strategies. Instructional materials experts rated design ($M = 3.87$), highlighting its visual appeal, logical layout, and learner-centered interface. Functionality also received favorable evaluations from all groups, suggesting that the mechanics operate smoothly and support instructional objectives effectively. Play-based approaches, including board and card games, are particularly effective for diverse learners and can be tailored to meet individual needs (Frederick *et al.*, 2019). Collectively, these findings affirm that SICM is a valid, pedagogically sound, and engaging instructional tool. Its combination of aesthetic design, content coherence, and functionality ensures that it is both educationally effective and motivating, aligning with best practices in game-based learning.

Instructional Utilization

Table 3: Instructional use as perceived by teachers

S. No	Item Statement	Mean	VD
1	I did not encounter any problems when I taught the topic (word problems in Integers).	4.00	Very Useful
2	I am satisfied with the behavior of my students with the board game.	4.00	Very Useful
3	My experience in moderating the (board) game is successful.	4.00	Very Useful
4	I did not encounter any problems while facilitating the game.	3.90	Very Useful
5	I am planning to use the SICM board game again in my class.	3.90	Very Useful
	Overall Mean	3.96	Very Useful

Table 3 reveals that the Strategic Integers' Cubes Mastery (SICM) board game was perceived by teachers as very useful in instruction, with an overall mean of 3.96. The highest-rated items —no problems in teaching the topic ($M = 4.00$), satisfaction with student behavior ($M = 4.00$), and successful experience in moderating the game ($M = 4.00$) — indicate that the board game effectively enhances teaching and classroom dynamics. These findings imply that the SICM board game successfully supports both teaching efficiency and learner participation. This aligns with Nakao's (2019) [9] study, which found that board games can combine educational content with interactive, enjoyable gameplay. Its integration fosters an enjoyable, low-stress learning environment where students remain focused and cooperative, reinforcing the game's potential as a sustainable instructional tool.

Table 4: Instructional use as perceived by students

S. No	Item Statement	Mean	VD
1	I enjoyed playing the board game.	3.78	Very Useful
2	The board game deepened my knowledge of word problems in Integers.	3.75	Very Useful
3	I am going to play the board game continuously.	3.28	Very Useful
4	The game increased my motivation to learn more about the topic (word problems in Integers).	3.85	Very Useful
5	I understand the game instructions well.	3.70	Very Useful
	Overall Mean	3.67	Very Useful

As presented in Table 4, students perceived the Strategic Integers' Cubes Mastery (SICM) board game as very useful ($M = 3.67$). The highest-rated item, "The game increased my motivation to learn more about the topic" ($M = 3.85$), suggests that the game effectively stimulated students' interest and engagement in mathematics learning. It aligns with the study by Assapun & Thummaphan (2023) [2], which found that playing games for learning helps learners gain knowledge identified in the syllabus and understand, practice, and use diverse learning and problem-solving strategies. This finding underscores the motivational potential of integrating play-based strategies in addressing abstract concepts such as integers. Conversely, the relatively lowest-rated item, "I am going to play the board game continuously" ($M = 3.28$), indicates that while the game was effective for learning, sustained engagement might require further variation in content or mechanics. This highlights the need to continually enhance game features to sustain long-term interest and maximize learning outcomes.

4. Conclusion

The study's findings revealed that the Strategic Integers' Cubes Mastery (SICM) board game effectively enhanced students' understanding of algebraic word problems involving integers and demonstrated strong alignment with the Grade 7 MATATAG curriculum. The game addressed common learning challenges such as interpreting problem statements, identifying operations, and performing integer computations, thereby promoting conceptual understanding. Its engaging design, with colorful visuals and interactive gameplay, fostered a fun, motivating learning environment that increased student participation. The systematic development process, grounded in expert consultation and iterative refinement, ensured that the final product was pedagogically sound and classroom-ready. Pilot implementation results revealed a significant improvement in students' post-test scores compared to their pre-test scores, confirming the game's effectiveness in improving mathematical performance. Expert evaluations rated the game "very good" across all criteria, further validating its quality and instructional soundness. Feedback from teachers and students indicated high usability, satisfaction, and sustained engagement, highlighting the game's potential as a

supplementary learning tool. Overall, the SICM board game exemplifies how game-based learning can transform abstract mathematical concepts into meaningful, enjoyable, and effective classroom experiences.

5. Recommendations

School administrators are encouraged to provide continuous professional development programs that equip teachers with the skills to integrate educational games like SICM into mathematics instruction effectively. Institutional support through funding, materials, and monitoring systems is also essential to sustain game-based learning initiatives. Teachers are advised to use SICM as a supplementary instructional tool to reinforce students' understanding of integers and algebraic word problems, and to facilitate reflective discussions that link gameplay experiences with mathematical concepts. Students should actively participate and collaborate during gameplay to develop problem-solving and critical thinking skills, treating the activity as a meaningful learning experience rather than mere entertainment. Future researchers are encouraged to explore the application of SICM across other mathematical domains, grade levels, and learning contexts, using comparative and longitudinal designs to assess its broader educational impact. Moreover, educational technology developers should collaborate with educators in designing digital versions of SICM that enhance accessibility, interactivity, and pedagogical value.

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