EDUCATION

Enhancing the Numeracy Skills of Grade 4 Pupils through the Use of SudoMath Game-Based Approach

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Abstract

This study aimed to determine the effect of the SudoMath Game-Based Learning Approach on the numeracy skills of Grade 4 pupils at a selected elementary school in Ozamiz City during the School Year 2025–2026. A classroom-based action research design using a single-group pretest–posttest approach was employed. The respondents of the study consisted of forty-two (42) Grade 4 pupils selected through purposive sampling. Data were collected using a researcher-made Numeracy Skills Test administered before and after the implementation of the SudoMath Game-Based Learning Approach. The research instrument was validated by education experts and tested for reliability, yielding an acceptable Cronbach's alpha value. Data were analyzed using mean, standard deviation, and paired t-test through Jamovi. Findings revealed that the numeracy skills of Grade 4 pupils before the implementation of the intervention were categorized as Did Not Meet Expectations, while after the implementation, pupils' performance improved to the Satisfactory level. Statistical analysis further revealed a very highly significant difference in the numeracy skills of Grade 4 pupils before and after the implementation of the SudoMath Game-Based Learning Approach. The study concluded that the SudoMath Game-Based Learning Approach is an effective instructional strategy in enhancing the numeracy skills of Grade 4 pupils through interactive and engaging mathematical activities.

Keywords: Mathematics Education; SudoMath Game-Based Learning Approach; numeracy skills; game-based learning; Grade 4 pupils; mathematics performance

1 Introduction

1.1 Context and rationale

Mathematics is considered one of the fundamental subjects in basic education since it builds the learner's logical reasoning, analytical skills, and problem-solving abilities. Many Grade 4 pupils are still having difficulty mastering basic numeracy skills such as addition, subtraction, multiplication, and division. These difficulties often result in poor academic performance and diminished confidence to learn the subject. Numeracy among elementary learners is one of the central goals of mathematics education in the 21st century. The term numeracy generally refers to the capacity to apply knowledge of mathematics in a variety of contexts. Numeracy is an important element of academic success and life competence. Recent research, however, revealed that a large number of students still struggle with number sense and problem-solving and basic arithmetic operations, which is reflected in their general achievement in mathematics (Rahayu et al., 2025). Schools are increasingly adopting digital and active learning environments, and thus have found it necessary to implement up-to-date strategies such as GBL to maintain student motivation and enhance the understanding of mathematical concepts as necessary (Cayang & Ursabia, 2024).

Numeracy skills are foundational in primary education, equipping learners with the ability to understand and apply mathematical concepts essential for both daily life and academic success. However, many Grade 4 pupils continue to face challenges in mastering numeracy, which can negatively affect their overall mathematical proficiency and future academic performance (Rahayu et al., 2025). In typical classroom settings, teachers often struggle to engage students who find traditional mathematics instruction uninteresting or difficult, especially in critical areas such as number operations and logical reasoning (Hui & Mahmud, 2023). To address these challenges, innovative instructional approaches like game-based learning (GBL) have gained prominence due to their potential to enhance student engagement and develop cognitive skills by integrating learning with interactive, enjoyable activities (Liang & Sitthiworachart, 2023).

Game-Based Learning has been identified as an effective tool in enhancing students' engagement and academic achievement by transforming traditional learning into an interactive and enjoyable experience. According to (Hui & Mahmud, 2023), GBL positively influences both cognitive and affective domains by improving students' mathematical knowledge, motivation, and attitude toward learning. Similarly, (Ergül & Doğan, 2022) found that using game-based approaches in teaching mathematical concepts such as place value helps pupils develop deeper conceptual understanding compared to conventional teaching. (Liang & Sitthiworachart, 2023) further assert that GBL provides opportunities for logical reasoning and creative problem-solving, which are vital for developing numeracy literacy among primary learners.

In the context of numeracy, game-based approaches allow pupils to visualize mathematical relationships, recognize patterns, and apply mathematical reasoning in problem-solving situations. As (Lee & Choi, 2020) emphasize, math games can significantly enhance early numeracy by promoting continuous engagement and facilitating conceptual mastery. Likewise, (Singh et al., 2021) developed "Math Zap," a card game that effectively improved students' numeracy performance and mental computation. These studies suggest that integrating digital or physical games in math classrooms nurtures not only basic skills but also higher-order thinking, which is essential in building mathematical confidence and fluency (Lamrani & Abdelwahed, 2020).

Despite the growing recognition of GBL's benefits, many classrooms continue to rely on conventional teaching methods that inadequately address students' diverse learning needs and preferences. As a result, numeracy deficits remain prevalent, often linked to low student motivation and limited exposure to stimulating and interactive learning strategies (Abbacan et al., 2025). Grade 4 pupils particularly require engaging tools that support both their cognitive development and affective domains such as motivation and interest (Dan et al., 2024). One promising instructional tool is the SudoMath game-based approach, which employs Sudoku-like puzzles designed to enhance essential skills like pattern recognition and logical reasoning, both crucial for numeracy development (Tengah, 2020). However, despite the potential of SudoMath and similar game-based interventions, studies exploring their effectiveness in the Philippine elementary education context remain sparse.

Empirical research consistently demonstrates that game-based learning interventions significantly improve numeracy skills by promoting active participation and adaptive thinking among learners (Cayang & Ursabia, 2024). For instance, (Lee & Choi, 2020) found that tablet-based math games increased early numeracy proficiency among rural primary students. In a similar vein, (Rahayu et al., 2025) reported that digital game-based learning boosted numeracy literacy and learner motivation in elementary education settings. Furthermore, SudoMath puzzles have been shown to foster pattern discovery and enhance logical thinking, directly supporting mathematical achievement (Tengah,

2020). Nevertheless, despite these promising outcomes, a notable gap exists regarding the contextualized application and measured impact of such game-based learning strategies on Grade 4 pupils.

While international studies have extensively examined game-based learning's role in enhancing numeracy, there remains a scarcity of localized research that evaluates the specific integration and impact of the SudoMath game-based approach on elementary mathematics teaching in the Philippines. Most prior investigations focus on broader digital game formats or traditional game designs rather than puzzle-based games crafted to develop logical reasoning and pattern recognition, which are essential cognitive skills underpinning numeracy (Ergül & Doğan, 2022). Importantly, (Miles, 2017) highlights a critical gap in understanding how innovative educational interventions translate into practical classroom outcomes, emphasizing the need for research situated within authentic learning environments. This research gap underscores the necessity to investigate SudoMath's effectiveness in enhancing numeracy skills among Grade 4 learners, including its influence on learner engagement and motivation.

The purpose of this study is to investigate the effectiveness of the SudoMath game-based learning approach in enhancing the numeracy skills of Grade 4 pupils within the Philippine elementary education setting. This study aims to assess how the integration of SudoMath puzzles impacts students' mathematical proficiency, focusing on critical areas such as pattern recognition, logical reasoning, and number operations. Additionally, the research seeks to explore the influence of the SudoMath approach on learners' engagement, motivation, and interest in mathematics. The study also intends to identify the challenges and opportunities experienced by both teachers and students in implementing this game-based strategy in the classroom. Ultimately, the findings aim to provide evidence-based recommendations for educators and curriculum developers, supporting the integration of innovative game-based learning methods that can improve numeracy outcomes and foster a more positive attitude toward mathematics among elementary learners.

This study aims to provide empirical evidence on the effectiveness of the SudoMath game-based approach in enhancing numeracy skills among Grade 4 pupils. Addressing numeracy challenges at this stage is pivotal for establishing a strong mathematical foundation that supports academic success and lifelong learning (Sari et al., 2025). Additionally, by integrating an innovative and interactive game-based learning tool, educators may foster increased motivation, interest, and cognitive engagement in mathematics, thereby mitigating issues related to student disengagement and math anxiety (Hidayat et al., 2024). The findings from this study will provide valuable insights for teachers, curriculum developers, and policymakers, facilitating the adoption of Sudoku-inspired games as an effective instructional strategy in primary education.

The SudoMath game-based approach is a carefully designed learning intervention that adapts Sudoku puzzles to the developmental level of Grade 4 pupils, aiming to improve numeracy through problem-solving and pattern recognition tasks (Tengah, 2011; Jinon, n.d.). This approach capitalizes on the inherent interactivity and engagement of game-based learning, which research has shown to enhance not only mathematical skills but also students' cognitive and affective domains, including motivation, interest, and academic achievement (Hui & Mahmud, 2023; Dan et al., 2024). By blending conventional mathematics instruction with the dynamic challenge of SudoMath puzzles, this study seeks to create a more stimulating and effective learning environment that promotes mathematical reasoning, accuracy, and student confidence in numeracy.

The SudoMath Game-Based Approach is an instructional strategy that integrates mathematical concepts into an interactive and engaging game format, designed to enhance numeracy skills among

Grade 4 pupils. This approach aims to make learning mathematics enjoyable and meaningful by incorporating problem-solving and critical thinking within a game context. Pupils actively participate in the learning process by solving puzzles and challenges that require application of numeracy concepts such as addition, subtraction, multiplication, and division.

SudoMath encourages students to think logically, strategize, and collaborate while working through progressively challenging tasks. This game-based learning method supports diverse learning styles and motivates pupils by combining fun and education, fostering a positive attitude towards mathematics. Research indicates that game-based learning improves student engagement, conceptual understanding, and academic performance in mathematics (Sari et al., 2025). According to (Johnson & Lee, 2024), educational games provide immediate feedback, which helps learners correct mistakes and reinforce learning. Furthermore, Gamal et al. (2025) found that integrating games in math instruction promotes sustained attention and increases retention of concepts among elementary pupils. The SudoMath approach aligns with constructivist learning principles, where learners build knowledge through active exploration and problem-solving within a supportive environment. Implementing the SudoMath game-based approach creates an interactive classroom atmosphere that enhances motivation and practical application of numeracy skills. This strategy is particularly effective for Grade 4 pupils as it addresses common difficulties in understanding abstract mathematical concepts by presenting them in tangible, game-related scenarios. Through consistent use, it is expected that pupils will not only improve their numeracy skills but also develop a lifelong interest in mathematics.

Implementing the SudoMath game-based learning approach begins with the teacher preparing thoroughly by understanding the game's objectives, rules, and how it aligns with the targeted numeracy skills. The teacher must gather all necessary materials, whether physical game boards or digital devices, and plan lessons that incorporate the game in a way that supports curriculum goals. Clear learning objectives should be communicated to the students so they know what skills they are expected to develop through this interactive method.

The teacher then introduces the SudoMath game to the pupils, explaining its relevance to mathematics and demonstrating how to play. Ensuring that the pupils grasp the instructions and game mechanics is crucial before moving forward. The class is organized into small groups or pairs to encourage cooperative learning, allowing students to discuss and solve problems together, which promotes communication and teamwork while reinforcing mathematical thinking. During the gameplay, the teacher plays a facilitative role, circulating among groups to provide support, clarify doubts, and stimulate higher-order thinking by asking probing questions. Immediate feedback is given to help learners reflect on their reasoning and correct mistakes, enhancing their understanding. Following the activity, the teacher leads a group discussion where pupils share their strategies, challenges, and lessons learned, fostering reflection and reinforcing the numeracy concepts practiced. Assessment of learning is conducted through formative tools such as quizzes or observations to measure progress compared to initial skill levels. Pupils' feedback on their experience with the game is also collected to evaluate its impact on their motivation and engagement. To maximize benefits, the SudoMath game is incorporated regularly over several lessons, gradually increasing in complexity to match pupils' advancing abilities. This method complements traditional instruction and creates a dynamic, motivating learning environment for numeracy skill development.

1.2 Statement of the problem

This study aims to determine the effect of the SudoMath game-based learning approach on the numeracy skills of Grade 4 pupils during the School Year 2025–2026 in Ozamiz City Central School. Specifically, it sought to answer the following questions:

1. What is the level of numeracy skills of Grade 4 pupils before the implementation of the SudoMath game-based learning approach?
2. What is the level of numeracy skills of Grade 4 pupils after the implementation of the SudoMath game-based learning approach?
3. Is there a significant difference in the numeracy skills of Grade 4 pupils before and after the implementation of the SudoMath game-based learning approach?

1.3 Null hypothesis

H_{01}: There is no significant difference in the numeracy skills of Grade 4 pupils before and after the implementation of the SudoMath game-based learning approach.

2 Methods

2.1 Research design

This study will employ a classroom-based action research approach using single pretest-posttest design. The pretest-posttest design is widely recognized in educational research for assessing the impact of an intervention by measuring learners' skills before and after implementation (Amalia et al., 2024). It enables the researcher to determine whether the game-based approach leads to significant improvements in numeracy mastery and engagement. This design is practical in classroom settings where control groups are difficult to establish, and it effectively captures changes within the same group over a set period (Dan et al., 2024). Digital and game-based learning interventions have shown positive effects on students' motivation and mathematical performance (Hui & Mahmud, 2023), supporting its use for evaluating SudoMath. By comparing pretest and posttest results, the study aims to show the game's contribution to improving both cognitive and affective domains in mathematics education.

2.2 Research setting

This will be conducted in a public elementary school located in Ozamiz City, Misamis Occidental, Philippines. A single section of Grade 4 pupils from various cultural, socioeconomic, and linguistic backgrounds, reflecting the community it serves. The Grade 4 level was specifically chosen as the focus group due to the critical importance of developing strong numeracy skills at this stage, which are foundational for future mathematical learning. The school's supportive environment and access to technological resources provided a conducive setting for implementing the SudoMath game-based learning intervention and assessing its impact on pupils' numeracy skills.

2.3 Respondents of the study

This study will involve 42 Grade 4 pupils enrolled in a public elementary school in Ozamiz City, Misamis Occidental, Philippines, for the school year 2025–2026. The participants will be selected using purposive sampling to ensure that they are currently active Grade 4 students and willing to participate in the study. The criteria for selection include enrollment in Grade 4 at Ozamiz City

Central School during the specified school year (2025-2026) and readiness to engage in the SudoMath game-based learning intervention. Only pupils whose parents or guardians consent to their participation will be included, ensuring adherence to ethical research standards. This selection aims to address the gap in research on the effectiveness of SudoMath game-based approach as a formative assessment tool in improving young learners' focus, understanding, and numeracy skills. By focusing on this group, the study provides insights into how SudoMath activities can enhance meaningful learning in Grade 4 Mathematics.

2.4 Research instruments

The study will use the following instruments as data-gathering tools.

A. SudoMath Numeracy Skills Assessment Test. This researcher-designed test was developed to evaluate Grade 4 pupils' mastery and problem-solving skills in numeracy concepts before and after the implementation of the SudoMath game-based learning approach. The test was created based on previous studies emphasizing the effectiveness of game-based learning in improving students' mathematical reasoning, engagement, and practical problem-solving abilities (Ergül & Doğan, 2022). It consists of 40 items structured around real-life mathematical problem scenarios, aligned with SudoMath gameplay activities conducted over four sessions spanning four weeks. Each session will last 60 minutes, including a 10-minute pretest, a 40-minute gameplay and instructional activity, and a 10-minute posttest. The test measures problem-solving performance through numerical operations, logical reasoning, and the application of numeracy concepts within meaningful contexts.

To assess pupils' mastery and problem-solving skills, the study will use a 5-point Likert scale, where 5 represents the highest level of proficiency and 1 the lowest: 38–40, Outstanding; 35–37, Very Satisfactory; 32–34, Satisfactory; 29–31, Fair; and 1–28, Poor.

The validity and reliability of the SudoMath Numeracy Skills Assessment Test were established through expert consultations and pilot testing. Mathematics educators reviewed the test content to ensure alignment with Grade 4 competencies in numeracy and problem-solving skills. A pilot study was conducted to assess clarity, coherence, and difficulty level, and Cronbach's alpha was used to measure internal consistency. Prior research confirms that assessments designed around game-based learning effectively enhance students' numeracy skills and engagement by connecting learning to real-world scenarios (Dan et al., 2024; Liang & Sitthiworachart, 2023).

B. Student Engagement and Motivation Questionnaire. This researcher-made questionnaire was designed to assess pupils' engagement and motivation in the SudoMath game-based learning environment. The instrument uses a 5-point Likert scale, with responses ranging from Strongly Disagree (1) to Strongly Agree (5), adapted from Song et al. (2025). It comprises 20 items categorized into four key constructs: Cognitive Engagement (5 items), Affective Engagement (5 items), Behavioral Engagement (5 items), and Motivation (5 items). These constructs evaluate how pupils interact with the game-based activities, their enthusiasm for learning numeracy, and their persistence in problem-solving tasks. This questionnaire is highly relevant to the study as it measures the impact of the SudoMath game on pupils' motivation and participation.

The instrument will be administered as both a pre-assessment before the intervention and a post-assessment after all gameplay sessions to allow comparative analysis of changes in pupil engagement and motivation. Previous studies show that game-based learning positively influences student collaboration, enthusiasm, and willingness to engage with challenging numeracy tasks (Rahayu & Firdaus, 2025).

The validity and reliability of this questionnaire were established through expert reviews and pilot testing with Grade 4 pupils. Mathematics educators assessed the questionnaire items for alignment with curricular goals and game-based learning objectives. Cronbach's alpha was used to confirm internal consistency, supporting the questionnaire's effectiveness in capturing cognitive, affective, and behavioral dimensions of student engagement and motivation (Rahayu & Firdaus, 2025).

The responses are interpreted as follows: 5 – Strongly Agree (4.20–5.00, Extremely High); 4 – Agree (3.40–4.19, High); 3 – Neutral (2.60–3.39, Moderate); 2 – Disagree (1.80–2.59, Low); and 1 – Strongly Disagree (1.00–1.79, Extremely Low).

C. Lesson Plan. In this study, the SudoMath game-based approach is integrated into the Grade 4 mathematics curriculum focusing on numeracy skills such as number operations, pattern recognition, and logical thinking. Each of the four sessions begins with a pretest to assess pupils' initial numeracy mastery, followed by a teacher-facilitated SudoMath gameplay activity where pupils collaboratively solve math problems embedded in the game. For example, pupils will work on pattern puzzles, number placement, and logical reasoning tasks designed to enhance numeracy concepts. After the gameplay activities, a posttest will be administered to evaluate learning gains and the impact of the SudoMath approach on pupils' mastery and problem-solving skills. Comparing pretest and posttest scores will provide data to assess the effectiveness of the intervention in improving numeracy understanding, critical thinking, and the practical application of math concepts in everyday situations (Lozano et al., 2023).

2.5 Data collection

Before conducting the study, the researcher will seek formal approval to conduct the study by submitting letters to the appropriate school authorities. Approval will first be sought from the Misamis University Research Ethics Board (MUREB) to ensure compliance with institutional and ethical research standards. A formal letter will then address to the Dean of the College of Education at Misamis University. Upon approval, the researcher will secure endorsement from the Program Head, followed by the submission of a request letter to the Division Office of Ozamiz City. After receiving clearance from the division office, permission will be sought from the School Principal of the public elementary school where the study will be conducted. Upon receiving approval from the Principal, letters will then be sent to the Grade Level Coordinator and the class Adviser to secure their consent before proceeding with any data collection activities. Each letter will clearly outline the study's objectives, methodology, and scope to ensure transparency and adherence to institutional policies. Following the acquisition of institutional approvals, the researcher will distribute informed consent forms to the parents or guardians of the Grade 4 pupils, along with assent forms for the pupils themselves. These documents will provide detailed information about the study's purpose, procedures, benefits, and potential risks, ensuring that parents formally agree to their child's participation and that pupils voluntarily assent to participate.

The study followed a single pretest-posttest design over 6 weeks, consisting of problem-solving tasks embedded within the SudoMath game. Data collection will be conducted over four sessions, each lasting approximately 60 minutes, spanning four weeks. Each session will begin with a pretest to assess the pupils' current numeracy skills, followed by gameplay and teacher-facilitated activities where pupils collaboratively engage in problem-solving tasks embedded within the SudoMath game. Each session will end with a posttest to evaluate immediate learning outcomes and skills gained.

In addition to these session-based assessments, a pre-intervention questionnaire assessing pupils' engagement and motivation will be administered before the first session to establish baseline data. Upon completion of the final session, a post-intervention questionnaire will be given to measure any changes in engagement and motivation. Mean scores from the pretests and posttests, along with data from the engagement and motivation questionnaires, will be analyzed to determine the effectiveness of the SudoMath approach in enhancing numeracy skills and pupil motivation. The use of standardized scoring rubrics and validated instruments throughout the study will ensure consistent, reliable, and objective measurement of pupil progress and the impact of the intervention.

2.6 Ethical considerations

Before conducting the study, the researcher will strictly observe all ethical standards to protect the participants' rights and welfare. Approval will be secured from the School Principal, Grade Level Coordinator, and class Adviser before any data collection begins, ensuring compliance with institutional and ethical guidelines. Informed consent will be obtained from parents or guardians of the selected Grade 4 pupils, and the pupils will provide their assent to confirm voluntary participation. Participants will be assured that they may withdraw at any time without consequences. Confidentiality and anonymity will be maintained by coding and securely storing all personal information. The study will also be designed to minimize any risk or discomfort, ensuring a safe and supportive environment throughout the process.

2.7 Data analysis

This study utilized several statistical methods for data analysis with the aid of JAMOVI software:

Frequency and percentage analyses were employed to examine the learners' level of mastery in numeracy skills before and after the implementation of the SudoMath game-based learning approach. These descriptive statistics helped in understanding the distribution and proportion of students across different mastery levels.

Mean and standard deviation were calculated both before and after the intervention. The mean scores represented the overall performance of the pupils, while the standard deviation provided insight into the consistency and variability of their responses.

A *paired sample t-test* was conducted to determine if there were significant differences in the learners' mastery and problem-solving skills before and after experiencing the SudoMath game-based learning approach. This inferential statistical test was used to evaluate the effectiveness of the intervention in enhancing students' numeracy abilities, analytical thinking, and application of mathematical concepts in practical contexts.

3 Results and discussion

3.1 Level of numeracy skills of Grade 4 pupils before the implementation of the sudomath game-based learning approach

Table 1 presents the level of numeracy skills of Grade 4 pupils before the implementation of the SudoMath Game-Based Learning Approach. The findings revealed that the overall performance of the pupils was categorized as Did Not Meet Expectations, with an overall mean score of (M = 27.73, SD = 2.08). This finding indicates that the pupils had low mastery of numeracy skills prior to the

implementation of the intervention, suggesting difficulties in understanding and applying basic mathematical concepts and operations.

Among the performance levels, the highest frequency was recorded under Did Not Meet Expectations (36, 85.7%) and a mean score of (M = 14.9, SD = 4.568). This was followed by the Satisfactory level (4, 9.5%) and (M = 32.8, SD = 0.957). Meanwhile, only (n = 2, 4.8%) of the pupils achieved the Very Satisfactory level, obtaining a mean score of (M = 35.5, SD = 0.707). Notably, no pupil reached the Outstanding and Fairly Satisfactory levels prior to the implementation of the intervention.

The findings indicate that the majority of Grade 4 pupils demonstrated low numeracy skills before the utilization of the SudoMath Game-Based Learning Approach. The dominance of pupils under the Did Not Meet Expectations category suggests that learners experienced considerable difficulty in understanding and applying basic mathematical concepts and operations. This may imply limited mastery of foundational numeracy competencies, which are essential for solving mathematical problems and performing classroom tasks effectively. The very small proportion of pupils who attained Very Satisfactory and Satisfactory ratings further emphasizes the need for instructional interventions that can enhance learner engagement, motivation, and comprehension in mathematics. The relatively low overall mean also reflects that pupils may have been exposed to traditional teaching strategies that were insufficient in addressing diverse learning needs and promoting active participation during numeracy instruction.

Several studies support the finding that learners often demonstrate low numeracy skills prior to the implementation of game-based learning interventions. According to Hui and Mahmud (2023), game-based learning significantly enhances both cognitive and affective domains in mathematics, indicating that traditional instruction alone is often insufficient in developing numeracy skills. Similarly, Dan et al. (2024) found that primary learners frequently struggle with mathematical understanding when digital game-based strategies are not yet introduced, highlighting gaps in foundational numeracy development. Ergül and Doğan (2022) further emphasized that pupils taught through conventional methods in place value lessons showed limited engagement and understanding compared to those exposed to game-based learning. In addition, Rahayu et al. (2025) reported that digital game-based learning significantly improves students' numeracy literacy, suggesting that learners' low initial performance may be attributed to lack of interactive and meaningful instructional approaches. Overall, these studies highlight the necessity of innovative, game-based strategies to address numeracy difficulties among elementary learners.

The findings imply the need for teachers to use innovative and learner-centered strategies, such as the SudoMath Game-Based Learning Approach, to improve pupils' numeracy skills. School administrators may support numeracy enhancement programs through training and instructional materials, while parents may assist learners through home-based activities and academic monitoring. Schools may also conduct remedial classes, peer tutoring, and mathematical games to address learning gaps and improve pupils' performance in mathematics.

Table 1. Level of numeracy skills of Grade 4 pupils before the implementation of the SudoMath game-based learning approach.

Performance level	Frequency	%	*M*	*SD*
Very Satisfactory	2	4.8	35.5	0.707
Satisfactory	4	9.5	32.8	0.957

Performance level	Frequency	%	*M*	*SD*
Did Not Meet Expectations	36	85.7	14.9	4.568
Overall	**42**	**100.00**	**27.73**	**2.08**

Note: 38–40 (Outstanding); 35–37 (Very Satisfactory); 32–34 (Satisfactory); 29–31 (Fairly Satisfactory); 1–28 (Did Not Meet Expectations).

3.2 Level of numeracy skills of Grade 4 pupils after the implementation of the SudoMath game-based learning approach

Table 2 presents the level of numeracy skills of Grade 4 pupils after the implementation of the SudoMath Game-Based Learning Approach. The findings revealed that the overall performance of the pupils improved to the Satisfactory level, with an overall mean score of (M = 34.53, SD = 0.64). This finding indicates that the intervention helped improve pupils' numeracy skills, suggesting better understanding and application of mathematical concepts after the implementation of the SudoMath Game-Based Learning Approach.

Among the performance levels, the highest frequency was recorded under Outstanding (14, 33.3%) and a mean score of (M = 39.3, SD = 0.83). This was followed by Fairly Satisfactory (13, 31.0%) and (M = 30.2, SD = 0.44). Meanwhile, (n = 11, 26.2%) of the pupils achieved the Satisfactory level with (M = 33.1, SD = 0.70), while the lowest frequency was observed under Very Satisfactory (4, 9.5%) and (M = 35.5, SD = 0.58). Notably, no pupil fell under the Did Not Meet Expectations category after the implementation of the intervention.

These results suggest that the SudoMath Game-Based Learning Approach contributed positively to the enhancement of pupils' numeracy skills. The absence of learners under the Did Not Meet Expectations category indicates that the intervention was effective in helping pupils attain at least the minimum expected level of mathematical competence. The increase in the number of pupils who reached the Outstanding level further implies that game-based learning may have strengthened pupils' engagement, participation, and understanding of mathematical concepts. The interactive and enjoyable nature of the SudoMath activities may have encouraged learners to actively solve problems, think critically, and practice mathematical operations with greater confidence. Moreover, the relatively low standard deviation across all performance levels indicates consistency in pupils' scores, suggesting that the intervention may have benefited not only high-performing learners but also those who previously struggled with numeracy skills.

Several studies support the positive effect of game-based learning in improving learners' numeracy skills, which aligns with the findings of this study. According to Sari et al. (2025), digital game-based learning significantly improves elementary students' numeracy literacy and engagement by making mathematical concepts more interactive and meaningful. Similarly, Cayang and Ursabia (2024) found that the use of game-based learning strategies effectively enhances students' mathematical skills, particularly in problem-solving and conceptual understanding. Abbacan et al. (2025) also emphasized that educational games contribute to better numeracy skill development among elementary learners by increasing motivation and active participation in learning activities. In addition, Ferasol et al. (2024) reported that integrating game-based innovations in mathematics instruction leads to transformative improvements in learners' numeracy performance and classroom engagement. Overall, these studies confirm that game-based learning approaches, such as SudoMath, play a significant role in enhancing pupils' numeracy skills and academic achievement.

The findings suggest that teachers should continue using game-based and learner-centered strategies to improve pupils' numeracy skills and motivation in mathematics. School administrators and curriculum developers may support this through instructional resources, teacher training, and numeracy programs, while parents may reinforce learning through simple math activities at home. Schools may also provide remedial classes, cooperative learning activities, and numeracy drills to further enhance pupils' mathematical proficiency.

Table 2. Level of numeracy skills of Grade 4 pupils after the implementation of the SudoMath game-based learning approach.

Performance level	Frequency	%	*M*	*SD*
Outstanding	14	33.3	39.3	0.83
Very Satisfactory	4	9.5	35.5	0.58
Satisfactory	11	26.2	33.1	0.7
Fairly Satisfactory	13	31.0	30.2	0.44
Overall	**42**	**100.00**	**34.53**	**0.64**

Note: 38–40 (Outstanding); 35–37 (Very Satisfactory); 32–34 (Satisfactory); 29–31 (Fairly Satisfactory); 1–28 (Did Not Meet Expectations).

3.3 Significant difference in the numeracy skills of Grade 4 pupils before and after the implementation of the SudoMath game-based learning approach

Table 3 presents the significant difference in the numeracy skills of Grade 4 pupils before and after the implementation of the SudoMath Game-Based Learning Approach. The findings revealed a very highly significant difference in the numeracy skills of the pupils before and after the intervention, as indicated by the computed t-value and probability value (t = 13.6, p = 0.001). Since the obtained p-value was less than the 0.05 level of significance, the null hypothesis stating that there is no significant difference in the numeracy skills of Grade 4 pupils before and after the implementation of the SudoMath Game-Based Learning Approach was rejected. Furthermore, the mean score of the pupils increased from (M = 17.5, SD = 7.91) before the implementation to (M = 34.5, SD = 3.83) after the implementation, indicating a substantial improvement in pupils' numeracy performance.

The significant finding suggests that the SudoMath Game-Based Learning Approach had a positive and meaningful effect on the numeracy skills of Grade 4 pupils. The notable increase in the mean scores after the intervention implies that pupils were able to better understand and apply mathematical concepts through interactive and engaging learning experiences. The game-based approach may have enhanced pupils' motivation, attention, and active participation during mathematics instruction, which contributed to improved academic performance. Moreover, the lower standard deviation after the implementation indicates that pupils' scores became more consistent, suggesting that the intervention benefited both low-performing and high-performing learners. This further implies that the SudoMath activities created an inclusive learning environment where pupils were encouraged to practice and strengthen their numeracy skills collaboratively and confidently.

No non-significant findings were observed in the study since the computed p-value (p = 0.001) was lower than the 0.05 level of significance. This indicates that all observed changes in the pupils' numeracy skills were statistically significant and were unlikely to have occurred by chance alone. The absence of non-significant results further strengthens the evidence supporting the effectiveness of

the SudoMath Game-Based Learning Approach as an intervention in improving mathematics performance among Grade 4 pupils.

Several studies support the significant improvement in learners' numeracy skills after the implementation of game-based learning interventions. According to Hui and Mahmud (2023), game-based learning significantly enhances students' cognitive development in mathematics, leading to improved understanding and academic performance. Dan et al. (2024) also found that digital game-based learning in primary mathematics education produces statistically significant gains in learners' achievement, reinforcing its effectiveness as an instructional strategy. Similarly, Ergül and Doğan (2022) reported that students exposed to game-based instruction in place value concepts performed significantly better compared to those taught using traditional methods. In addition, Rahayu et al. (2025) emphasized that digital game-based learning interventions lead to significant improvements in elementary pupils' numeracy literacy and overall mathematics performance. These findings collectively support the present study's result that SudoMath Game-Based Learning significantly improves Grade 4 pupils' numeracy skills.

The findings of the study have important implications for teachers, school administrators, curriculum planners, and parents. Teachers are encouraged to integrate game-based learning approaches such as SudoMath into mathematics instruction to promote learner engagement, critical thinking, and mastery of numeracy skills. School administrators may provide support through instructional materials, professional development seminars, and training programs focused on innovative teaching strategies in mathematics. Curriculum planners may consider incorporating more interactive and learner-centered activities into the mathematics curriculum to address learners' diverse needs and abilities. Parents may also reinforce learning at home by encouraging children to participate in educational games and numeracy-related activities. To sustain and further improve pupils' performance, schools may conduct regular numeracy enhancement programs, mathematics camps, peer tutoring sessions, and collaborative problem-solving activities that foster continuous learning and enjoyment in mathematics.

Table 3. Significant difference in the numeracy skills of Grade 4 pupils before and after the implementation of the SudoMath game-based learning approach (paired-samples t-test, N = 42).

Phase	*M*	*SD*	*t*	*p*	Decision
Before implementation	17.5	7.91	13.6***	0.001	Reject H_{01}
After implementation	34.5	3.83			

Note: ***$p < 0.001$ (very highly significant); **$p < 0.01$ (highly significant); *$p < 0.05$ (significant).

4 Summary, findings, conclusions and recommendations

4.1 Summary

This study aimed to determine the effect of the SudoMath Game-Based Learning Approach on the numeracy skills of Grade 4 pupils at a selected school in Ozamiz City during the School Year 2025–2026. Specifically, it examined the level of numeracy skills of Grade 4 pupils before and after the implementation of the SudoMath Game-Based Learning Approach and the significant difference in the pupils' numeracy skills before and after the intervention. The study focused on Grade 4 pupils to determine how the use of SudoMath game-based activities influences pupils' understanding and application of mathematical concepts and operations.

4.2 Findings

This study yielded the following findings:

1. The level of numeracy skills of Grade 4 pupils before the implementation of the SudoMath Game-Based Learning Approach was categorized as Did Not Meet Expectations.
2. The level of numeracy skills of Grade 4 pupils after the implementation of the SudoMath Game-Based Learning Approach improved to the Satisfactory level.
3. There was a very highly significant difference in the numeracy skills of Grade 4 pupils before and after the implementation of the SudoMath Game-Based Learning Approach.

4.3 Conclusions

Based on the findings of the study, the following are the conclusions:

1. Grade 4 pupils demonstrate low numeracy skills before the implementation of the SudoMath Game-Based Learning Approach.
2. Grade 4 pupils demonstrate improved numeracy skills after the implementation of the SudoMath Game-Based Learning Approach.
3. The SudoMath Game-Based Learning Approach significantly improves the numeracy skills of Grade 4 pupils.

4.4 Recommendations

Based on the findings and conclusions of the study, it is recommended that:

1. Grade 4 Mathematics teachers integrate the SudoMath Game-Based Learning Approach and other learner-centered activities in classroom instruction to improve pupils' numeracy skills, engagement, and participation in Mathematics.
2. School administrators and school heads provide instructional materials, mathematical games, and teacher training programs that support the effective implementation of game-based learning approaches in Mathematics education.
3. Future researchers may conduct similar studies using larger samples, different grade levels, or other game-based learning strategies to further validate and expand the findings on the effectiveness of the SudoMath Game-Based Learning Approach in enhancing numeracy skills.

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