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Leveling Up Mathematical Skills: The Effectiveness of Game-Based Learning

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Abstract. This quantitative study, using an experimental approach, aimed to determine the effectiveness of game-based learning in teaching mathematics. The respondents were fourth-grade pupils in an elementary school in Aleosan, North Cotabato, Philippines. Data were gathered using a pre-test questionnaire adopted by the researcher and a researcher-made post-test questionnaire validated by experts. The data were analyzed using weighted means and paired and unpaired t-tests. Results revealed that academic performance in mathematics during the pre-test was poor. However, there was a highly significant difference between the scores before and after the intervention. There was also a significant difference between the control and experimental groups (t=-2.337, p=0.022), with the experimental group (M=19.18) scoring significantly higher than the control group (M=16.31). Based on the findings, it can be affirmed that implementing game-based learning strategies in mathematics instruction is highly effective, resulting in a notable enhancement of learners' academic performance compared to conventional teaching methods. Moreover, the results encourage teachers to revisit their instructional materials and integrate game-based learning materials aligned with specific learning objectives. Additionally, the study provides substantial evidence that game-based learning significantly enhances academic performance in mathematics compared to traditional instructional resources.

Keywords: Academic achievements; Effectiveness; Game-Based learning; Mathematics; Quantitative; Philippines.

1.0 Introduction

Numerous fields rely on mathematics as an essential tool worldwide. Not only is it a field of research and a subject taught in schools, but it also serves as a playground for learners as a challenging subject that can be regarded as everyone's modern-day survival kit (Zigler & Loos, 2017). The development of civilizations is strikingly evident wherever a high priority is placed on mathematical knowledge. The way that man lives and understands the universe revolves around numbers, and computations are essential to the development of an individual and our current society (Abd Algani, 2022).

Unfortunately, many learners feel stressed and anxious when they have to do math, which also affects their performance (Sokolowski & Ansari, 2017). Several nations all over the world are deeply concerned about math achievement gaps. One of the countries experiencing the same trends, pressures, and concerns is the Philippines. Based on the 2019 Trends in International Mathematics and Science Study (2020), the Philippines came in "significantly lower" than any other nation that took part in the math assessments for grade 4. It received the lowest score of any of the 58 participating countries, with a score of 297.

According to the findings of a research study conducted in Tanzania and selected schools in Mpumalanga Province, South Africa, ineffective learning and assessment strategies, institutional resources, failure to

comprehend instructions, and instructor didactic strategies are all factors in exam failure or poor performance of learners (Mazana et al., 2019; Mabena et al., 2022).

When games are encouraged in a classroom setting, teamwork and social contact will be developed, and math anxiety will be reduced more effectively, according to Dondio et al. (2022). Game-based Learning (GBL) will significantly enhance the teaching-learning process in mathematics and one that can be applied in the classroom with ease. The ability to support and promote learners' motivation, and games are a highly effective part of this teaching technique. It is a technique that uses the notion of playing a game to fulfill learning goals, whether they relate to knowledge, abilities, or attitudes (Falciani, 2020). Using educational games is successfully employed in teaching and can enhance mathematical learning skills, based on a review of the data from 30 research that were analyzed (Hasanah & Andayani, 2022).

Based on a study conducted in Trinidad and Tobago's primary schools, instructors responded "strongly agreed" that using games to teach young children can be quite effective at making complex ideas simple, and in primary school classrooms, game-based learning should gradually become more prevalent among learners (Pinder, 2016). However, insufficient empirical evidence exists to substantiate the efficacy of game-based learning in enhancing academic performance compared to traditional instructional resources. Additionally, the study of Munda, Endrinal, and Nequinto (2024) and Munda and Endrinal (2022) applied game-based learning with their experimental high school participants. Their study found statistically significant differences in the pre-test and post-test performances of their student subjects after applying the educational games. The use of educational game-based activities in the projects COUNTS and Math-stery, respectively, helped improve the numeracy skills of the high school students.

Furthermore, limited research has been conducted on developing game-based learning materials that align with specific learning objectives. The main objective of the study was to level up the mathematical skills of fourth-grade learners through game-based learning as an effective strategy in teaching. The specific objectives were determining the academic performance of the respondents before the intervention, determining the academic performance of the respondents after utilizing the intervention, determining the significant difference between the academic achievement before and after utilizing the game-based strategy in terms of learners' scores, and determining the significant difference between control and experimental group in academic performance in mathematics.

2.0 Methodology

2.1 Research Design

The research utilized an experimental research design by creating instructional and learning material utilizing a game-based strategy. It determined the academic performance of Aleosan Central Grade IV learners before and after the intervention. It also assessed the effectiveness of game-based learning in improving academic achievement in mathematics. Before administering the test, a meticulously crafted scoring key was developed. This key was designed to clearly identify the correct answer for each question, aligning precisely with the course objectives and content during the intervention period. Subsequently, during the scoring process, each learner's responses were thoroughly compared to the key. Points were then awarded for correct answers, typically granting one point for each accurately chosen option, while incorrect or unanswered items received no points.

2.2 Research Respondents

The respondents of this study were the grade IV learners of an elementary school in Aleosan, North Cotabato, who are officially enrolled in the academic year 2023-2024. The study employed complete enumeration in which the population of grade IV was composed of two sections assessed through a pre-test; however, only the low-performing group was given an intervention. Thus, the other section served as the control group. According to Ortega and Sumayo (2024), using complete enumeration is appropriate since it allows the researchers to get good generalizability.

2.3 Research Instrument

The researcher created sixteen (16) game-based learning instructional and learning materials suitable for one (1) month of experimentation and could be applied to specific mathematics topics. The instructional and learning

materials were validated by three (3) experts or validators before being used. The sixteen (16) game-based learning instructional and learning materials were used from Week 1 to Week 4, except Fridays. They were aligned with the target learning competencies in Mathematics Most Essential Learning Competencies (MELCs) of the Department of Education.

In Week 1 of the experimentation, which started in the 2nd Week of the 1st Quarter of Grade IV Mathematics class, there were two most essential learning competencies: the learner rounded numbers to the nearest thousand and ten thousand (M4NSIb-5.2) and ordered numbers up to 100,000 in increasing or decreasing order (M4NSIb-13.4). In Week 3, the most essential learning competencies were that the learner multiplied mentally 2-digit by 1-to 2-digit numbers with products up to 200, explained the strategies used (M4NSId-42.3), and solved routine and non-routine problems involving multiplication of whole numbers, including money, using appropriate problem-solving strategies and tools (M4NSId-45.4).

For Week 2 of the experimentation, the most essential learning competencies included the learner multiplying numbers up to 3-digit numbers by up to 2-digit numbers without or with regrouping (M4NSIc-43.7) and estimating the products of 3- to 4-digit numbers by 2- to 3-digit numbers with reasonable results (M4NSIc-44.2). In Week 4, the learner solved multi-step routine and non-routine problems involving multiplication and addition or subtraction using appropriate problem-solving strategies and tools (M4NSIe-45.5).

To determine the academic performance of Central Grade IV learners before and after the intervention, a pre-test adopted from K12DepEd (2020) entitled "Grade 4 Self-Learning Modules" was utilized. For the post-test, a researcher-made questionnaire validated by experts was employed. Pre-test and Post-test were pilot-tested with a Cronbach alpha result of .865 and .872. The 40-item multiple choice pre-test measured learners' current level of achievement with a scoring of one point each for the correct item, and the 40-item multiple choice post-test measured their achievement after the Game-Based learning method had been implemented with a scoring of one point per correct item.

2.4 Statistical Analysis

After one (1) month of experimentation, the evaluation results were gathered. The collected data were calculated using statistical tools appropriate to this study. A Paired T-test was used to determine if there was a significant difference between academic achievement before and after utilizing the game-based strategy in terms of learners' scores. Also, the Unpaired T-test was used to determine if there was a significant difference between the control group and the experimental group.

2.5 Ethical Considerations

The researchers ensured that the gathered data were utilized to fulfill the study's objectives only while adhering to ethical guidelines and protocols. Subsequently, the respondents' voluntary engagement was sought through an informed consent form (Royeras & Sumayo, 2024). All the data gathered were treated with utmost privacy and used for research purposes only and ensured that the respondents were in complete anonymity (Redocto & Sumayo, 2024).

3.0 Results and Discussions

3.1 Academic Performance

Pre-test

Table 1. Descriptive statistics of the academic performance in Mathematics during pre-test

Variables	Minimum	Maximum	Mean	SD	Interpretation
Group A	6	23	11.36	3.78	Poor
Group B	4	20	11.33	3.83	Poor

The findings presented in Table 1 reveal that both Group A and Group B demonstrated poor academic performance in mathematics during the pre-test, as evidenced by mean scores of 11.36 for Group A and 11.33 for Group B. It conforms with the results based on the 2019 Trends in International Mathematics and Science Study (2020); the Philippines came in "significantly lower" than any other nation that took part in the math assessments for grade 4 and received the lowest score of any of the 58 participating countries, with a score of 297.

The results suggest that it is plausible that learners encountered difficulties in comprehending and understanding given problems, particularly those presented in English and situational form, raising questions about the efficacy of teachers' strategies in imparting mathematical knowledge. This is also supported by the Deficit Theory established by Rebecca Eller (1989), which tries to explain why learners with disadvantages typically fail frequently. In this context, the disadvantages that the learners experienced were low comprehension in situational form.

This observation aligns with the findings of Mazana et al. (2019), who identified didactic strategies employed by mathematics teachers' factors influencing academic performance. As highlighted by Zhang (2022), learners' anxiety about mathematics is directly correlated with their teachers' teaching strategies. Ismael et al. (2021) found that certain teacher behaviors, such as quick pacing, excessive notetaking, abundant exercises, and punitive measures, significantly intensify mathematics anxiety. It solidifies the theory of Sigmund Tobias (1971), the concept of the Debilitating Anxiety Model, where learners' performance is affected by their fear or anxiety. The notably low mean scores results underscore the urgency of implementing intervention or improvement strategies to enhance the mathematical proficiency of learners in both groups.

Post-test

Table 2. Descriptive statistics of the academic performance in Mathematics during post-test

Variables	Minimum	Maximum	Mean	SD	Interpretation
Group A (Control)	3	26	16.31	4.45	Poor
Group B (Experimental)	7	32	19.18	6.25	Average

Table 2 presents valuable insights into the post-test performance of two distinct groups in the field of mathematics. Group A, referred to as the control group, exhibits a mean score of 16.31, categorized as "poor" according to the legend. In this present study, the findings imply that learners in this group are performing below the expected level in rounding numbers to the nearest thousand and ten thousand, ordering numbers up to 100 000 in increasing or decreasing order, multiplying numbers up to 3-digit numbers by up to 2-digit numbers without regrouping, and multiplies mentally 2-digit by 1-to 2-digit numbers with products up to 200 but not really on multiplying numbers up to 3-digit numbers by up to 2-digit numbers with regrouping and estimating the products of 3- to 4-digit numbers by 2- to 3- digit numbers since it is in traditionally way of teaching where in the teacher-centered classroom setting that may lead to lack of learners' engagement. If there is a lack of learners' engagement, academic boredom and disinterest follow and may also be contributing factors, resulting in difficulties in comprehension, understanding, and overall learning.

The result of the study conforms to the study of Yeh et al. (2019); the majority of elementary Mathematics classrooms in Taiwan continue to be dominated by traditional teacher-led instruction, leading to a persistent lag behind the expected level of academic accomplishment. The findings align with Tularam and Machisella's (2018) study, highlighting the significant role of teachers as instructors who determine the teaching-learning methods. Often, learners are perceived as having knowledge gaps that teachers must fill with information, leading to a separation of mathematical education from learners' daily experiences. This lack of engagement can result in academic boredom, as emphasized by Xie (2021) and Ozerk (2020). Xie's (2021) study underscores the importance of engagement in preventing boredom, while Ozerk's (2020) study categorizes academic boredom as a negative deactivating emotion that adversely affects goal achievement in a learning environment.

Conversely, Group B, identified as the experimental group using game-based learning, exhibits a mean score of 19.18, classified as "average." The same study result was presented in the study of Yeh et al. (2019), which describes a two-year experiment with 215 elementary learners from grades 2 to 3 in a game-based learning environment. They discovered that students' achievement in mathematics has increased because of this experiment, particularly in terms of word problems and calculation.

In the present study, the finding implies that most of the learners were able to answer rounding numbers to the nearest thousand and ten thousand, ordering numbers up to 100 000 in increasing or decreasing order, multiplying numbers up to 3-digit numbers by up to 2-digit numbers without regrouping, and multiplies mentally 2-digit by

1-to 2-digit numbers with products up to 200 but not really on multiplying numbers up to 3-digit numbers by up to 2-digit numbers with regrouping and estimating the products of 3- to 4-digit numbers by 2- to 3- digit numbers.

The integration of game-based learning in mathematics class appears to have a positive impact, fostering an environment where learners are unafraid to try and make mistakes that lead to learning. These current findings resonate with Mera et al. (2021) emphasis on errors as learning opportunities could have positive consequences for learning. Errors generated during learning are beneficial for later correct-recall. Despite this, it should be considered that if learners do make errors, the literature suggests that receiving corrective feedback is essential. Thus, a more in-depth understanding of the advantages of experiencing errors could promote the idea that failure is an important part of constructive learning and that the active exploitation of mistakes is essential in education.

3.2 Comparison of the Academic Performance in Mathematics Before and After Utilizing Game-Based Learning

Table 3. Analysis for the difference in the academic performance in Mathematics

Variable	Mean	Mean Difference	t	df	p-value
Pre-test	11.33	-7.850	-6.666**	38	0.000
Post-test	19.18				

*- Significant at 5% level of significance
**- Highly Significant at 1% level of significance

The presented findings in Table 3 strongly support the rejection of the null hypothesis, as the p-value falls below 0.01 or 1%. This signifies a highly significant contrast in scores before and after the intervention (t=-6.666, p-value=000). Specifically, the results indicate an improvement in scores following the intervention (pre-test= 11.33, post-test=19.18), emphasizing the effectiveness of game-based learning in enhancing mathematical academic performance but urging to extend the period in conducting game-based learning to yield more effective and comprehensive results. It is also observed in the study of Mao et al. (2021) that Game-based learning demonstrated a significant and positive overall effect on learners' critical thinking.

The game-based learning conducted during the intervention was for week 1, with the most essential competencies of rounding the numbers to the nearest thousand and ten thousand and ordering numbers up to 100 000 in increasing or decreasing order were Math Dice Rounding Numbers, Mathgical Card Number, Numerical Sequence Game with Paper Coins, and Block Arrangement. For Week 2, the most essential competencies of multiplying numbers up to 3-digit numbers by up to 2-digit numbers without or with regrouping and estimating the products of 3-to 4-digit numbers by 2-to 3-digit numbers with reasonable results were Multiplication Learning Activity, Math Clues: Clap or Snap, Optimize Math Puzzle, and Balland the Spinners. For week 3, the most essential learning competencies of multiplying mentally 2-digit by 1-to 2-digit numbers with products up to 200 and solving routine and non-routine problems involving multiplication of whole numbers were Navigation of Balls of Product, Multiplication Bingo Challenge, Interactive Circle Problem Solving Activity, and Stone Toss Game. For week 4, the most essential competencies of solving multi-step routine and non-routine problems involving multiplication and addition or subtraction were Interactive Graphing Exercise, Math Clues: Clap or Snap, Optimize Math Puzzle, and Animal Picture Questioning with Step Exercise.

The results of this study were supported by Munda, Endrinal, and Nequinto (2024) and Munda and Endrinal (2022), which showed that using game-based activities to teach in the COUNTS and Math-stery projects really helped students improve their math skills. Researchers conducted a study that revealed statistically significant disparities in the pre-test and post-test scores of the student participants following the implementation of educational games. Additionally, the previous study by Russo et al. (2021) indicated that most primary teachers self-reported playing mathematical games at least once per week in their classrooms. Games were used for different pedagogical purposes, including as a "warm-up" activity, introducing new mathematical concepts, consolidating skills and knowledge, and practicing fluency. Interestingly, playing cards and dice, oral games, pen and paper, and other games requiring minimal or no materials were the most popular choices for teachers.

Non-digital games demonstrated superior effectiveness compared to digital games. Games lowered math anxiety more effectively when they promoted social and cooperative interactions that were controlled by the length of the intervention and the type of gameplay (Dondio et al., 2023).

Game-based learning fosters engagement, motivation, and a renewed interest in learning mathematics through active participation, excitement, and joy of learners derived from the games. This dynamic approach contributes to a comprehensive understanding of concepts, ultimately leading to elevated academic achievement. The Game-based Learning approach is anchored to the Constructivism Learning Theory developed by Jean Piaget and Lev Vygotsky, in which learners participate in the process of solving the problem by interacting with their surroundings. The acknowledged capacity to captivate learners and ensure their full participation is one of its strengths (Brau, 2020).

The current study was reported on the study of Hui and Mahmud (2023), emphasizing the entertainment element in Game-based learning, which leads learners to approach learning with enthusiasm. Based on the study of Falciani (2020) and Brezovszky et al. (2019), the enjoyment derived from games seems to positively influence factors such as student motivation, math fluency, and adaptive number knowledge. Additionally, academic interest was proven to significantly determine academic performance (Mappadang et al., 2022).

Moreover, Dondio et al. (2023) emphasized that teachers in their study believe that game-based learning aids in the development of the four key skills emphasized in the Australian Curriculum: Applied Mathematics (ACARA, 2019) — comprehension, fluency, problem-solving ability, and logic. Interestingly, non-digital games exhibited greater efficacy compared to digital counterparts. Their study suggests that games are particularly effective in reducing math anxiety when they facilitate social and cooperative interactions, contingent on the intervention duration and game type.

The current study underscores the importance of collaborative learning present in game-based learning as a cornerstone for developing both social and cognitive skills. Additionally, insights offered by Adipat et al. (2021) study that it delves into the role of game-based learning in mindset development and growth.

3.3 Comparison of the Academic Performance in Mathematics Between Control and Experimental Group

Table 4. Analysis for the difference in the academic performance in Mathematics

Variable	Mean	Mean Difference	t	df	p-value
Control	16.31	-2.87	-2.337*	68.83	0.022
Experimental	19.18				

*- Significant at 5% level of significance
**- Highly Significant at 1% level of significance

Table 4 shows the difference between the control and experimental groups in academic performance in mathematics. The result shows that there is a significant difference between the control and experimental group (t=-2.337, p=0.022), which reveals that the experimental group (M=19.18) is significantly higher than the control group (M=16.31). The same result was reported in the study of Lei et al. (2022), revealing that Game-Based Learning taught students significantly more than traditional instruction in that intervention was not applied.

The present study suggests that the intervention or treatment implemented with the experimental group, which likely involved Game-Based Learning, had a positive impact on their academic performance compared to the control group. Game-based learning effectively boosts academic achievement in Mathematics. These findings emphasize the significance of Game-Based Learning in driving improvements in academic performance.

According to the study of Zhong (2019), game-based learning transforms the educational paradigm from a teacher-centered approach to one where learners actively participate in teamwork to grasp new concepts. This approach not only enhances cognitive abilities but also develops communication and teamwork skills. By incorporating game design elements into the learning process, an immersive and enjoyable educational environment is created, fostering learner initiative, creativity, and collaborative learning.

Furthermore, Wang and Zheng's (2021) research emphasized that the adoption of game-based learning methods proves highly beneficial for improving academic performance in mathematics. Mao et al.'s (2022) investigation explores the broader implications of game-based learning, focusing on its impact on the critical thinking of learners. A study by Wardoyo et al. (2020) underscores the analytical approach that employs gain-score methodology, which involves scrutinizing and assessing the learning outcomes of both the experimental group exposed to learning games and the control group to evaluate their efficacy. The analyses revealed that the implementation of game-based learning significantly enhances learning outcomes.

4.0 Conclusion

Based on the result of this study, game-based learning indicates a positive shift in learners' academic performance; thus, improvement is still needed. More so, the student-centered approach is the preferred learning environment of learners as it promotes engagement rather than lecturing. Notably, game-based learning emerges as a potent strategy for enhancing academic proficiency in mathematics, proving its effectiveness compared to traditional teaching methods.

Based on the findings and conclusions, educators are encouraged to adopt game-based learning that accounts for the diverse needs and potential learning barriers of learners. They should consider adjusting their teaching approaches to ensure better understanding and comprehension among learners. Furthermore, it is advisable for the Department of Education (DepEd) to explore, research, and implement game-based learning tailored to design a curriculum that aligns with current educational needs.

Future researchers are urged to conduct studies over an extended period to yield more effective and comprehensive results. It is also encouraged to give the other factors aside from the teachers' pedagogy and strategies in teaching that influence learners' learning process in mathematics.

5.0 Contributions of Authors

The authors confirm the equal contribution in each part of this work. All authors reviewed and approved the final version of this work.

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7.0 Conflict of Interests

All authors declare that they have no conflicts of interest.

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