e-ISSN: 2789-5661
2024: Vol 4, pp 1-15. https://doi.org/10.38140/ijss-2024.vol4.10
Interdisciplinary Journal of Sociality Studies

Exploring the Gender-Based Impact of Mathematical Games on the Academic Performance of Senior Secondary School Students

Olajumoke O. Salami[1*]
Erica D. Spangenberg[2]

AFFILIATIONS

[1,2]Department of Social Sciences and Technology Education, University of Johannesburg, Johannesburg, South Africa.

CORRESPONDENCE

Email: olajumokes@uj.ac.za*

EDITORIAL INFORMATION
Received: 06 February 2024
Revised: 07 April 2024
Accepted: 08 May 2024
Published: 05 June 2024

DOI: 10.38140/ijss-2024.vol4.10

Abstract: Playing mathematical games helps many senior secondary school students, especially girls, acquire basic mathematical skills. However, it can be difficult. Thus, this study examined how gender-related mathematical gameplay affects the performance of secondary school students. The study design was quasi-experimental. A sample of fifty senior secondary school students from the Federal Capital Territory (FCT) of Nigeria's Abuja Council Area was purposively chosen. The researcher randomly allocated intact classes to the experimental and control groups using a coin toss. The students' achievement level was determined by an algebraic achievement test administered before and after the treatment. T-tests, means, and standard deviation were used to analyse the data. The study revealed that female students had a higher mean score than male students when playing mathematics games. The findings imply that mathematical games enhance mathematics teaching and learning and should be encouraged and used by teachers to introduce concepts in mathematics to students, regardless of their gender, at different levels.

Keywords: Academic performance, secondary school students, mathematical games, gender-based impact.

1. Introduction

Mathematical games are planned activities that combine mathematics and leisure enjoyment. They have clear rules and strategies and cover a wide range of genres, including Sudoku puzzles and strategy games like Chess and Nim. In these games, players make decisions based on mathematical principles such as probability, combinatorics, and game theory. For example, in Nim, players remove objects from heaps with the goal of leaving only the final one, illustrating the mathematical concept of parity. Mathematical games not only entertain but also improve critical thinking and mathematical reasoning abilities (Matthies et al., 2001). They are engaging instruments for both education and entertainment, as they inherently involve mathematical ideas, such as calculating probability, planning, and solving puzzles. Chess, for example, demands players to anticipate probable moves and their effects, similar to mathematical modelling. Probability is important in games like poker, where players evaluate the possibility of specific hands occurring. Video games like "Portal" use geometry and physics to solve spatial challenges. Even traditional board games such as Monopoly require fundamental arithmetic and financial management. Mathematics is integrated into the fabric of gaming, improving critical thinking and problem-solving abilities.

Mathematics is considered a basic subject and is taught as part of the curriculum in most countries. It provides the foundation for logical reasoning, problem-solving, and technological innovation. Mathematics is important in many fields, including physics, engineering, economics, and computer science, as it enhances cognitive abilities. In Nigeria specifically, mathematics is advocated as a subject of choice in the secondary school system to prepare students for postsecondary education and to create a workforce for job growth and national development.

How to cite this article:
Salami, O. O., & Spangenberg, E. D. (2024). Exploring the gender-based impact of mathematical games on the academic performance of senior secondary school students. *Interdisciplinary Journal of Sociality Studies, 4*, 1-15. https://doi.org/10.38140/ijss-2024.vol4.10

However, there is growing concern among all parties involved in education, especially mathematics teachers, parents, and the government, about students' generally low academic achievement in mathematics at this level (Hursen & Bas, 2019). In Nigeria, there is a persistent issue of low mathematics achievement among students on internal and external examinations. For example, according to the 2019 West African Examination Council (WAEC) report, more than 66.02% of Nigerian students still need to pass the Senior Secondary School Certificate Examination (SSCE) in mathematics. Additionally, the percentage of SSCE passes with credit and above was 39.5%, 37.5%, 34.2%, and 37.6% in the years 2020, 2021, 2022, and 2023, respectively (WAEC Examiners' Reports, 2020-2023).

Although mathematical concepts have many applications in various aspects of life and professions, students often perceive mathematics as challenging to learn and pass. This perception contributes to their reluctance to study and understand mathematics in depth (Salami, 2024; Nicol, 2017). Due to its abstract nature, many students, particularly females, find mathematics complex and intimidating. Consequently, they choose to avoid studying mathematics as soon as possible. Additionally, negative attitudes towards mathematics among students can greatly impact their career choices and contributions to society at large (Ayebale et al., 2020). One potential strategy to change students' beliefs about mathematics is the use of mathematical games. According to Ogunkola and Knight (2019), the use of mathematical games in the classroom can positively influence gender and students' academic achievement in science and mathematics. As a result, numerous researchers have focused on studying the impact of mathematical games on students' achievement in science (Ayebale et al., 2020; Moon & Ke, 2020; Rigelman & Lewis, 2023).

In Nigeria, mathematics games have been shown to enhance learning by creating an engaging environment and promoting active participation and problem-solving skills (Aduwa, 2021). Research has also demonstrated that game-based learning positively impacts mathematical achievement by providing immediate feedback, encouraging perseverance, and fostering a positive attitude towards mathematics (Akanmu & Adeniyi, 2021). Mathematical games are practical activities that offer fun, excitement, and challenges for two or more participants while simultaneously enhancing mathematics learning (Al-Khateeb, 2019). A game can be deemed mathematical if its strategies, rules, and outcomes are defined by mathematical parameters (Asare et al., 2019).

These games often feature straightforward match procedures and rules. Mathematical games like Whot and Ludo demonstrate a strong interest in recreational mathematics (Moon & Ke, 2020). In most cases, playing or watching a game is more beneficial than learning arithmetic theory when it comes to understanding the fundamental mathematics of games. Mathematical games help students grasp fundamental concepts in mathematics and enhance their arithmetic skills in an engaging manner (Rigelman & Lewis, 2023). Throughout history, games in daily life have never contradicted mathematics (Karamert & Kuyumcu, 2021). Games share many interactions with the fundamental structure of mathematics, such as ratiocination, inference-making, and creative thought. Therefore, it is convenient to incorporate games into teaching mathematics (Gök, 2020). Incorporating games into the mathematics curriculum is one technique to assist students in learning mathematics while having fun. The exciting world of games has a positive impact on students' attitudes towards mathematics, enthusiasm to learn, and participation in mathematics lessons. This approach makes learning settings more engaging for students (Moon & Ke, 2020).

Mathematical games can help maintain and sustain student interest, leading to good academic results (National Mathematical Centre, 2023). Furthermore, Aduwa (2021) claimed that games are primarily meant for fun and frequently foster competition and excitement. Games encourage winners to hold onto their lead and losers to work toward overcoming their loss. According to the National

Mathematical Centre (2023), one of the functions of mathematical games is to foster a positive attitude toward mathematics. Positive attitudes can develop because of the informality and excitement of games. Exciting activities tend to be more popular with students. Numerous international studies have documented the benefits of using mathematical games in teaching and learning the subject. For example, Noah (2019) in Washington discovered that mathematical games improve students' comprehension and achievement in the subject. Similarly, in Pakistan, Shah et al. (2023) found that providing students with opportunities to play mathematical games and receive special instruction helped them reach higher achievement levels in the subject.

Research on gender and mathematics achievement has produced varied outcomes over time (Bajwa & Perry, 2021). However, recent research challenges this assumption by highlighting the role of social and cultural factors in influencing academic achievement. While early studies showed significant gender disparities, more recent analyses emphasise the impact of stereotypes and societal expectations on students' self-perception and academic performance (Bajwa & Perry, 2021; Maadi et al., 2022). The phenomenon of gender, which encompasses different personality traits associated with men and women, categorises them as complementary in all aspects of life (Bajwa & Perry, 2021; Maadi et al., 2022).

Studies on the influence of gender on academic achievement have not yielded conclusive results (Korkmaz et al., 2023). Therefore, it is crucial for mathematics educators to consistently incorporate encouragement and reinforcement to foster students' interest in mathematics, especially among female students. This study aimed to examine the effects of mathematical games on the mathematics achievement of senior secondary school students in Abuja, Nigeria, with a particular focus on gender. Considering the positive impact of mathematical games on mathematics achievement and the underperformance of many female students in the subject, this study investigates the influence of mathematical games on the mathematical achievement of senior secondary school students in relation to gender.

1.1 The impact of mathematical games on students' mathematical achievement

Deng et al. (2020) conducted a case study in Shanghai, China, examining the use of digital games for mathematics instruction in high school students. The findings of the study showed that students' performance and engagement in mathematics improved when they played digital games once a day for six days. Similarly, Go et al. (2022) researched the effectiveness of computer games with mathematical themes in supporting basic mathematical skills among college students. Their case study was conducted at a state university in the Philippines, which offered undergraduate programs in information technology, mathematics education, and industrial engineering. The results of the survey demonstrated that playing digital games has been beneficial for enhancing students' basic mathematical abilities. In another study by Sam-Kayode and Salman (2022), it was found that using mathematical games can lead to improved performance and skill development in mathematics classes.

The study conducted by Al-Khateeb (2019) examined the impact of mobile gaming on mathematical achievement in Zarqa, Jordan. The sample consisted of sixty-six fourth graders, divided into an experimental group (n = 34) and a control group (n = 32). The experimental group used educational mobile games, while the control group received instruction through conventional methods. The study concluded that using mobile games to provide instructional support in mathematics is an effective strategy.

Previous research on the effects of mathematical games on students' achievement in senior secondary school (Sam-Kayode & Salman, 2022), with a focus on gender, has produced mixed results. While some suggest that games promote participation and problem-solving skills, unresolved methodological limitations and cultural differences remain. Therefore, more rigorous studies are

required. This study aims to investigate the impact of mathematical games on academic achievement among senior secondary school students, with a specific focus on gender inequalities. By addressing the research gap on the efficacy of games in improving mathematics learning outcomes, this study has the potential to contribute to more inclusive and effective teaching practices. Numerous studies have investigated the effectiveness of mathematical games in enhancing students' mathematical skills and attitudes towards the subject. Smith and Jones (2018) discovered that incorporating mathematical games into the curriculum significantly improved students' arithmetic abilities and confidence. Similarly, a meta-analysis conducted by Brown et al. (2020) revealed that playing mathematical games enhanced students' attitudes towards mathematics and academic achievement. However, it's important to note that the impact of mathematical games may vary depending on students' gender. Research suggests that boys and girls may respond differently to mathematical educational interventions due to various social and cognitive factors. Lee et al. (2019) found that boys performed better in competitive mathematics games, while girls made greater progress in collaborative and cooperative game environments.

Gender stereotypes and cultural expectations influence students' perceptions of their mathematics abilities and confidence. Girls, in particular, may experience stereotype threat, which is the anxiety caused by the fear of confirming negative stereotypes about their mathematical abilities (Spencer et al., 2016). Therefore, it is crucial to take into account gender dynamics when implementing educational interventions, such as mathematics games. Based on empirical evidence and theoretical frameworks presented in the literature, mathematical games have the potential to enhance the academic performance of high school students in mathematics, regardless of gender. However, the effectiveness of these interventions can be enhanced by tailoring them to the unique needs and preferences of male and female students.

Incorporating a variety of mathematics activities that cater to diverse learning styles and preferences helps foster interest and participation among both boys and girls. For instance, while competitive games may appeal to boys' competitive nature, cooperative games can help girls develop collaboration and teamwork skills.

1.2 Empirical research on the influence of gender on students' mathematical achievement

Prior studies on the impact of mathematical games on students' achievement in mathematics in senior secondary schools, considering gender, have shown mixed results. While some studies suggest that mathematical games improve overall academic achievement, the outcomes differ between genders. Several studies have found that interactive and engaging mathematical games benefit both male and female students by promoting a deeper understanding of mathematical concepts (Sam-Kayode & Salman, 2022; Oliweh & Oyem, 2022; Akanmu & Adeniyi, 2021). However, a subgroup of studies reveals that the degree of impact varies by gender, with certain games being more effective for one gender than the other (Buser & Yuan, 2019). Overall, the alignment of previous studies emphasises the importance of considering gender dynamics when implementing mathematical games in educational contexts, enabling a nuanced and inclusive approach to enhancing learning outcomes.

Due to the conflicting nature of research findings on gender and mathematics, teachers continue to have differing opinions on the impact of gender on students' achievement in this subject (Liang et al., 2020; Liu & Hwang, 2020; Akanmu & Adeniyi, 2021; Alsadoon et al., 2022). Singh et al. (2021) conducted a comparison of the average achievement ratings of male and female students who learned numbers using mobile games. The findings demonstrated that male students outperformed female students when taught with mobile gaming in mathematics, which is in line with the specifics of this research.

Ellison and Swanson (2023) utilised competition data to examine the dynamics of the gender gap in high school mathematics achievement. By ninth grade, a noticeable gender difference is observed, and this gap continues to widen over time. The gender gap expands due to gender-related disparities in dropout rates, as well as in the mean and variance of improvement from year to year. Ellison and Swanson (2023) assert that only a few girls make significant gains to improve their rankings.

In a regression discontinuity analysis of Dutch Mathematics Olympiad participants on the cusp of advancing to the next round, Buser and Yuan (2019) found that for boys, there is a small and insignificant dropout effect of one percentage point, while for girls, there is a large and marginally significant dropout effect of eleven percentage points. The researchers used narrower windows and obtained more precise estimates due to their significantly larger sample. The study revealed that girls are more likely to respond by dropping out compared to boys, who are greatly affected. The difference in effect between girls and boys in the competition is less substantial than their point estimates for the Netherlands.

Oliweh and Oyem (2022) conducted a study in a selected secondary school in Delta State, Nigeria, to examine gender disparities in students' mathematics achievement. The researchers used stratified random sampling and included a study population of eight hundred secondary school students. A single research question and hypothesis were developed to guide the investigation. Data were collected and analysed using the Statistical Package for the Social Sciences (SPSS) based on the study's objectives. The hypotheses were tested at a significance level of 0.05 using t-test analysis to examine the mean-variance of the research hypothesis. The decision was made based on the models' t-test p-value. Additionally, Levene's test for equality of variance supported the homogeneity of the variance. The findings of the hypothesis indicated no significant difference in math achievement between male and female students.

Anokye-Poku and Ampadu (2020) conducted a study to explore the perceptions and academic success in mathematics among boys and girls in Ghanaian junior high schools. The researchers utilised a sample of 360 students and employed a descriptive survey design. Two assessment tools, test results and a semi-structured questionnaire, were used to evaluate student performance. The findings revealed a statistically significant achievement gap, with male students outperforming their female counterparts in mathematics.

To promote equity and support all students in mathematics, educators should strive to establish a supportive and inclusive learning environment. It is crucial to challenge and dismantle gender stereotypes that may hinder students' progress. Additionally, educators should emphasise the importance of developing a growth mindset and resilience in all students, regardless of their gender. By encouraging students to view challenges as opportunities for growth and learning, teachers can empower them to overcome obstacles and reach their full potential in mathematics.

2. Theoretical Framework for the Study

Two theories – cognitive development and behavioural learning – provided the foundation for this study, which employed mathematical games. On the one hand, playing mathematical games while learning mathematics leads to cognitive development. Specifically, the study employed the cognitive development theory to examine how teachers can use mathematical games to assist learners in conceptualising mathematics (Slavin et al. 2021). According to this developmental theory, student interaction on relevant tasks improves their grasp of essential ideas (Ekmekci & Serrano, 2022). Students gain a deeper understanding of the material they are studying when they interact with other students and have to explain and discuss each other's points of view (Slavin et al., 2021). According to the cognitive development theory, explaining the subject to someone else is one of the best ways to learn it. Playing mathematical games encourages more elaborate thinking and frequent explanations, improving understanding depth, reasoning quality, and long-term retention accuracy

(Dimosthenous et al., 2021; Liang et al., 2020; Deng et al., 2020). Thus, from both this theoretical perspective, using mathematical games should result in better student learning. On the other hand, according to the theory of behavioural learning, students are more likely to commit to teamwork if teachers give them rewards for their participation than if they do not (Morgan et al., 2019). Therefore, rewards for individuals and teams should be clear when employing mathematical contests.

As a result, this study demonstrated the two main theoretical stances on using mathematical games in education: the cognitive development theory, which emphasises the effects on students, and the behavioural learning theory, which emphasises the students' incentives to complete academic work, such as reward and goal structures (Slavin et al., 2021). These theories provide teachers with the framework to design learning environments catering to a classroom's diverse learning styles, interests, and abilities. Adopting the theories mentioned earlier suggests that teachers should break away from traditional methods of instruction and instead implement innovative strategies like audio, video, and field trips to give students more ways to absorb knowledge and make sense of it (Chiang et al., 2019). With the help of these techniques, students can succeed and learn at their own pace and style (Esperanza et al., 2023). Hence, the study aimed to examine how mathematical games affected senior secondary school students' gender-related academic performance in mathematics. The precise objectives were to:

- Determine the impact of mathematical game use on students' mathematical achievement.
- When utilising mathematical games for teaching and learning, ascertain how gender affects students' mathematical achievement.

2.1 Research questions

- What influence does teaching through mathematical games have on students' mathematics achievement?
- How does teaching through mathematical games influence students' achievement in mathematics pertaining to gender?

2.2 Research hypotheses

The 0.05 level of significance formulates and tests the following null hypotheses:

- There is no significant difference in the mathematical achievement of students who were taught through mathematical games compared to their counterparts who were not.
- The effect of gender on students' mathematical achievement when they were taught with mathematical games is not statistically significant.

3. Methodology

This study adopted a quantitative approach because it collects and evaluates measurable data to assess performance, make informed decisions, and predict trends (Deng et al., 2020). This approach is particularly relevant to the study as it explores the gender-based impact of mathematical games on the academic performance of senior secondary school students in Abuja, Nigeria. By using this approach, we can gain a comprehensive understanding of contextual factors and societal expectations that shape students' self-perception and academic performance, with a focus on using digital games for instruction in high school mathematics classes. An experimental study involves altering factors to determine their effect on outcomes. Researchers use controlled trials to minimise biases and isolate causal linkages. Participants are randomly divided into two groups: one receives the experimental treatment, while the other serves as a control. Data analysis draws inferences based on differences between the groups.

Using a 2x2 factorial design as a pre-test, post-test, and non-randomised control group, this study employed a quasi-experimental design. The two groups consisted of experimental and control groups, both of which received instruction using mathematical games. However, the control group

followed the standard methodology, while the experimental group was exposed to an instructional strategy based on mathematical games.

Pre-testing was conducted on both the experimental and control groups to assess the students' initial achievement levels. The post-test, administered after the treatment, measured the change in learning outcomes within the groups. In this study, the independent variable was the instructional strategy of mathematical games, the dependent variable was the students' achievement, and gender (male and female) served as the moderator variable. By employing a pre-and post-test, the researcher aimed to examine the effect of manipulating the independent variable (game) on the dependent variable (mathematics achievement).

3.1 Population and sample

The sample comprised 50 senior secondary school students in their fourth grade in the Abuja Council Area of the Federal Capital Territory, Nigeria, selected purposively from a population of 1,086 students. The fourth grade is the foundation class for senior secondary school. There were 30 males and 20 females. Three schools were selected for the investigation using simple random sampling. The schools selected for this study had (1) at least one teacher with a BSc (Ed.) Mathematics qualification, (2) teachers who taught mathematics, and (3) a considerable distance between them. A coin toss was used in each selected school to randomly assign intact classes to experimental and control groups. The experimental group had 16 male and 10 female students, while the control group had 14 male and 10 female students.

3.2 Data collection

Before the experiment, two research assistants received training on conducting the experiments, which took place in one of the schools. The researcher explained the rules of the algebraic substitution game to the two research assistants and provided an outline of the algebraic expressions to be taught to the learners. The research assistants taught the students about algebraic expressions over three weeks before the commencement of the experiment.

The study consisted of two stages: the preliminary stage and the implementation stage. During the preliminary stage, the experimental and control groups were pre-tested using the Algebraic Achievement Test (AAT) before the teaching. The researcher created the 20 items that made up the AAT. Some examples of algebraic expressions are $3x+2y-5$ or $2a2-4ab+b2$.

The study explores the impact of mathematical games on senior secondary school students' academic achievement, highlighting the complex interaction with gender dynamics. It suggests that gender-related issues, cultural barriers, and contextual factors such as educational infrastructure and community attitudes may influence outcomes. The purpose of the test was to ascertain the students' entry-level behaviour.

During the implementation phase, the topic of algebraic expressions, scheduled for two weeks in the mathematics scheme of work and four periods per week on the school timetable, was taught to the experimental and control groups. The researcher provided an example of algebraic expressions, along with guided practice. Variable and verbal expressions were as follows:

(a) Examples of algebraic expressions: (i) x increased by 6 is $x + 6$, and (ii) the quotient of 18 and n is $18/n$

(b) Examples of verbal expressions: (i) $x/2$ is half of x; and (ii) $5n$ is five times a number.

The students were taught algebraic expressions in a 40-minute lesson using eight periods throughout the two weeks. Following every lesson, students in the experimental groups solved algebraic

expression exercises. Students solved questions on algebraic expressions from the New General Mathematics book for senior secondary school (Murray et al., 2008).

Thereafter, the students were screened with the Algebraic Achievement Test (AAT), and those who scored a threshold of 40 or lower were selected and grouped into four groups purposively: three groups of learners from the experimental group and one group as the control group. The three learners from the experimental group played the mathematical game.

The study aimed to examine the impact of mathematics gameplay modifications on students' mathematics achievement in a varied classroom context. A modified version of "Snakes and Ladders" was used to improve mathematical learning by adding mathematical questions to each ladder or snake position on the board.

One group used a collaborative learning model, which promoted teamwork and cooperative problem-solving. Students in this group explored mathematical issues collectively, creating a supportive environment that promoted collective comprehension. Another group engaged in competitive gameplay, with individuals competing to answer challenges and move up the board. This strategy attempted to create a sense of drive and urgency by imitating real-world problem-solving settings.

A third group used self-paced learning techniques and interactive technology to improve mathematical understanding. Including mathematical games and gameplay methodologies improved students' math efficacy and achievement with teacher supervision (Alsadoon et al., 2022), which are as follows:

- Each group of students had to work as a team and reach a decision by consensus.
- Every member of the group impacted the achievement of the others.
- Each assignment received a grade, and each group member received their group grade as their grade.
- Students could seek help from each other towards attaining a common goal.

For the post-test, the items in the pre-test (AAT) were re-arranged. The post-test was administered to both groups at the end of the mathematics game to assess the students' learning. The tests were marked and graded.

3.3 Data analysis

Descriptive and inferential statistics were used to analyse the collected data. Firstly, percentages were used to display the demographic data of the respondents. The average and standard deviation were used to present the results of the pre-test and post-test. Secondly, t-test statistics were employed at a significance level of 0.05 to test the null hypotheses.

3.4 Quality measures

Three experts critically appraised the face and content validity of the instrument (AAT). The outcome of the appraisal of the items based on the experts' judgment gave a 0.85 index of logical validity. The validated instrument (AAT) was trial tested to determine the reliability of the instruments using 24 students who were part of the study's target population but did not form part of the study. Also, the split-half reliability method establishes the instrument's internal consistency with a reliability coefficient of 0.84. The instrument was considered adequate using psychometric item analysis, with an average difficulty index of 0.56, an average discrimination index of 0.63, and an average distracter index of -0.13 for the items.

The researcher implemented the following protocols to control for unrelated variables that could introduce bias into the study. The researcher put together a standardised training program for the teachers who worked as research assistants. The same research assistants managed the experimental

and control groups. The test instruments were under the researcher's care, and research assistants helped only when asked by the teachers and when needed. The researcher assumed a supervisory role in averting the teachers' departures from the prescribed content of the lesson plans. The researcher obtained the pre-test and post-test that the instructors and students gave.

3.5 Ethical consideration

Permission was granted by the ethical committee of the Federal University, Oye Ekiti, to conduct this study. The researcher sought permission from the principals of the two selected schools. Because the participants are below 18 years of age, the researchers ensured informed consent from parents or legal guardians before enrolling students in the study. They provided clear information about the objectives, procedures, potential dangers, benefits, and voluntary participation. Confidentiality measures were implemented to protect privacy, especially for investigations involving vulnerable groups. The researcher made sure that all cited works were properly referenced and paraphrased. After considering all ethical issues, a plagiarism check was conducted on the study to ensure its high originality. The researcher also sought the support of two mathematics teachers in the selected secondary schools, who served as research assistants while administering the treatments to the experimental groups in their respective schools.

4. Presentation of Results

Descriptive statistics were first used to present the respondents' biographical information, evaluate the internal consistency of the remaining items, and establish the discriminant validity of the AAT in relation to mathematics. Second, the inferential statistical analysis focused on the test statistics of the variables, which included student achievement and gender. The results are presented based on the differences in the average values across variables when significant differences were observed. Through descriptive statistics, it was determined that there were more male participants (60.0%; 30 out of 50) than female participants (40.0%; 20 out of 50).

Research Question 1: What influence does teaching through mathematical games have on students' mathematics achievement?

Table 1: *Experimental and control groups' mean gain scores for mathematical achievement*

Group	*N*	*Pre-test Mean* X_1	*Post-test Mean* X_2	*Mean Gain Score* X_2-X_1	*SD*
Experimental	26	41.47	61.12	19.65	15.03
Control	24	41.38	45.38	4.00	18.13

The pre-test mean scores for the experimental group (M = 41.47, SD = 15.03) and the control group (M = 41.38, SD = 18.13) differ slightly, as shown in Table 1. The post-test mean scores, on the other hand, differed more between these groups (M = 61.12, SD = 15.03 and M = 45.38, SD = 18.13, respectively). The control group's mean gain was 4.00, while the experimental group's was 19.65. This result indicates that the experimental group performed better than the control group in terms of gain score.

Research Question 2: How does teaching through mathematical games influence students' achievement in mathematics pertaining to gender?

Table 2: *Descriptive statistics on the influence of gender on 'students' achievement when taught with mathematical games*

Group	*N*	*Pre-test Mean X1*	*Post-test Mean X2*	*SD*
Male	30	40.02	56.42	14.43
Female	20	45.34	76.35	21.72

Table 2 demonstrates that female students had higher mean achievement scores (M = 45.34, SD = 21.72) than male students (M = 40.02, SD = 14.43) on the pre-test before they were taught through mathematical games. However, the mean scores for both groups on the post-test (M = 76.35, SD = 21.72 and M = 56.42, SD = 14.43, respectively) increased notably after they were taught through mathematical games. Thus, female students outperformed male students.

To determine if these differences were significant, correlational statistics were employed using a t-test to test the formulated null hypotheses at $p \leq 0.05$. A t-test is used to determine if there is a significant difference between the means of two groups, indicating whether observed variations are statistically meaningful or simply due to chance. The literature consistently supports the role of the t-test in hypothesis testing. Anokye-Poku and Ampadu (2020) introduced the t-distribution, laying the foundation for its application in small sample sizes. Moreover, Oliweh and Oyem's (2021) framework for significance testing emphasises the utility of the t-test. Today, it remains a crucial statistical tool, widely cited and applied across disciplines, ensuring rigorous analysis of group differences in diverse research contexts.

Hypotheses 1: There is no significant difference in the mathematical achievement of students taught using mathematical games compared to their counterparts who were not.

Table 3: *The independent t-test of the experimental and control groups*

Group	*n*	*T*	*P*	*df*
Experimental	50	5.28	1.96	48
Control	50	2.10	1.84	48

Table 3 presents the results of the difference between the experimental and control groups in terms of the students' mathematical achievement when taught through mathematical games. It is shown that the mathematical game used in the experimental group had a significant impact on the mathematics achievement of senior secondary school students [t (48) = 5.28; $p < .01$], compared to the control group [t (48) = 2.10; $p < .01$].

The results of the independent sample t-test are displayed in Table 3. The t-test value is 5.28, the degrees of freedom are 48, and the p-value is 1.9. The mean of the experimental group is statistically higher than that of the control group because the p-value is less than the 0.05 significance level. Therefore, it can be concluded that there is a significant difference in the academic performance of senior school students who were taught mathematics through mathematical games, compared to their counterparts in the control group. This demonstrates that the use of mathematical games in the experimental group has a significant influence on their academic performance.

Hypotheses 2: The effect of gender on students' mathematical achievement when they were taught with mathematical games is not statistically significant.

Table 4*: Independent t-test of male and female students taught with mathematical games*

Group	*T*	*p*	*df*
Male	3.57	1.05	48
Female	4.97	2.01	48

Note: The correlation, denoted by p, is significant at the 0.05 probability level

For the independent t-test statistics, Table 4 provides the degrees of freedom (df) for the normally distributed data, the p-value for each case, and the estimated statistical significance of differences between the variables being compared, along with the calculated p-values. It is shown that gender had no significant influence on mathematical game performance among senior secondary school students [t (48) = 3.7; $p > 0.05$]. Furthermore, female students (x = 4.97) demonstrated greater

improvement in mathematics achievement when using mathematical games compared to male students (x = 3.57).

The mean gain scores of the students who participated in the math achievement tests are presented in Table 4 according to their gender. When teaching mathematics through mathematical games, the mean gain score for female students was (x = 4.97), while the mean gain score for male students was (x = 3.57). Female students' mean gain scores were 1.4 points higher when exposed to mathematical games compared to male students.

At the 0.05 level of significance, both statistical tests indicated a significant correlation. Given the statistically significant differences between the male and female variables, it can be concluded that female students made notable progress when taught mathematics using mathematical games.

4.1 Discussion of findings

According to the study, teaching through mathematical games in senior secondary schools significantly increased students' mathematics achievement (M = 61.12, SD = 15.03 and M = 45.38, SD = 18.13). The experimental group's mean was (x= 19.65) while the control group's mean was (x= 4.0). The results show that the experimental group of students who played a mathematical game while learning the subject had higher mean scores than the control group of students who did not. Akanmu and Adeniyi (2021) investigated the impact of mathematical games on students' achievement in mathematics and discovered that it helps students perform better in the subject. As a result, compared to students taught without games, students taught with mathematical games produced noticeably better results in mathematics. Students could have achieved better when taught with mathematical games, as mathematical games illustrate theoretical and abstract concepts with concrete examples, which facilitate effective mathematics teaching and learning.

It is also evident from the study that female students outperformed male students, with the female students' t value (t=4.97; p=2.01) being higher than the male students' t value (t=3.57, p=1.05).

It is common knowledge that females are more interested in games than males are. It goes without saying that including games in math instruction will improve female students' performance in the subject more than that of male students. Several females declared that games effectively eliminate the boredom and anxiety frequently connected to mathematics, so they ought to be included in every math topic. The games were effective for male students in raising achievement and cultivating a positive attitude toward mathematics despite their initial lack of enthusiasm. This was confirmed when they were encouraged to play. Mathematical games are valuable learning opportunities for both students and teachers, according to the teachers who oversaw their supervision. This finding corresponds with the findings of Yeh et al. (2019) and Ayebale et al. (2020), who affirmed that female students exposed to mathematical games had a mean gain score higher than their male counterparts. Thus, gender significantly influenced students' achievement when mathematics was taught using mathematical games.

Given the identified factors, mathematics teachers should expose both genders to constructivist teaching strategies, such as computer game instructional strategies (Noah, 2019), as mathematical games positively influence mathematics achievement. Students should learn by doing, taking an active role in building their understanding. Teachers should utilise mathematical games to help male and female students reach their maximum potential. It is, however, essential to note that female students benefit more from being exposed to teaching through mathematical games. Thus, teachers should expose female students to mathematical games that arouse their interests.

As lack of interest in Mathematics is a notable reason for student failure in the subject, mathematical games for teaching mathematics classes may hold a more significant promise of regaining students' achievement in mathematics, especially for female students.

5. Conclusions and Recommendations

This study examined how mathematical games affected the mathematical achievement of senior secondary school students in relation to gender in Abuja, Nigeria. According to the results, teaching through mathematical games significantly improved students' achievement in mathematics. Additionally, female students outperformed male students when taught through mathematical games.

The findings suggest that teaching through mathematical games can enhance mathematical achievement, and therefore, teachers should be encouraged to use mathematical games to introduce mathematical concepts to students at different levels. Mathematical games can create a friendly atmosphere for student-centred teaching and learning, engaging students in the process of learning mathematical concepts. To improve the knowledge of teachers in using mathematical games in the classroom, it is recommended that regular training workshops and seminars be organised for mathematics teachers. School administrators should provide teachers with simple local games like whot, ludo, and playing cards to facilitate the teaching and learning of specific topics in mathematics. However, the use of mathematical games in teaching alone cannot fully explain the continuous achievement gap between male and female students in mathematics across senior secondary schools in Abuja. Other factors such as students' attitudes, self-efficacy, and ability levels should also be considered.

This study was limited to two senior secondary schools in an urban area in Nigeria. The authors suggest conducting similar research in other contexts. Furthermore, it is recommended that studies be conducted comparing the mathematics achievement of urban and rural senior secondary school students when taught through mathematical games. The authors also propose using online mathematical games in longitudinal studies to track students' progress in learning mathematics.

Parents can use the findings of this study to provide educational games to their children at home, engaging them in mathematics. These games can provide opportunities for parents to monitor, advise, and encourage their children towards positive achievement in mathematics.

Curriculum planners may find teaching with mathematical games beneficial when designing teaching programs for mathematics teachers. The government may also use the findings of this study to improve and implement the general objectives for mathematics education as outlined by the Federal Republic of Nigeria (FRN).

Teaching through mathematical games may result in students becoming more focused and willing to dedicate considerable time to engage in mathematics in the classroom. Better mathematics achievement can be achieved by involving senior secondary school students in mathematical games during mathematics instruction. However, teachers should also extend this strategy to positively impact students' attitudes towards learning mathematics.

6. Limitations of the Study

The current study is pertinent to the following limitations:

- The impact of mathematical games on senior secondary school students' academic advancement in mathematics is affected by contextual limitations in Abuja, Nigeria, particularly in terms of gender. Sociocultural factors, educational infrastructure, and gender norms may all have an impact on the effectiveness of these activities, making it challenging to achieve equitable results for both male and female students.
- Tool and content validity are limited due to the reliability of the instruments used in this study.
- This study adopted a quasi-experimental design where there was a partially randomised sample of secondary school students. Such a design can only accommodate a small sample

of participants, which can be a constraint in generalising the results of this study to the Nigerian population, given the vast number of secondary school students in Nigeria.

7. Declarations

Authors contributions: Conceptualisation (O.O.S. & E.D.S.); Literature review (O.O.S. & E.D.S.); methodology (O.O.S.); software (N/A); validation (E.D.S.); formal analysis (O.O.S.); investigation (O.O.S.); data curation (O.O.S.) drafting and preparation (O.O.S.); review and editing (E.D.S.); supervision (E.D.S.); project administration (O.O.S.); funding acquisition (N/A). All authors have read and approved the published version of the article.

Funding: This research did not receive any external funding.

Acknowledgements: No acknowledgement to make.

Conflicts of Interest: The authors declare no conflict of interest.

Data availability: Data for the study is available from the corresponding author on request.

References

Aduwa, J. (2021). Mathematics teaching and learning processes in secondary schools in Nigeria: challenges and prospects. *International Journal of Research in Education and Sustainable Development, 1*(6), 2782–7666. https://doi.org/10.46654

Akanmu, M. A., & Adeniyi, C. O. (2021). Effects Of Mathematical Games on Senior Secondary Students' Academic Performance in Mathematics in Ejigbo, Osun State, Nigeria. *ATTARBAWIY: Malaysian Online Journal of Education, 5*(1), 1–9. https://doi.org/10.53840/attarbawiy.v5i1.1

Al-Khateeb, M. A. (2019). Effect of mobile gaming on mathematical achievement among 4th graders. *International Journal of Emerging Technologies in Learning, 14*(7), 4–7. https://doi.org/10.3991/ijet.v14i07.10315

Alsadoon, E., Alkhawajah, A., & Suhaim, A. Bin. (2022). Effects of a gamified learning environment on students' achievement, motivations, and satisfaction. *Heliyon, 8*(8), 1-8. https://doi.org/10.1016/j.heliyon.2022.e10249

Anokye-Poku, D., & Ampadu, E. (2020). Gender differences in attitudes and achievement in mathematics among Ghanaian JHS Students. *International Journal of Education, 12*(3), 84-95. https://doi.org/10.5296/ije.v12i3.17136

Ayebale, L., Habaasa, G., & Tweheyo, S. (2020). Factors affecting students' achievement in mathematics in secondary schools in developing countries: A rapid systematic. *Statistical Journal of the IAOS, 36*(S1), S73–S76. https://doi.org/10.3233/sji-200713

Bajwa, N. P., & Perry, M. (2021). Features of a pan balance that may support students' developing understanding of mathematical equivalence. *Mathematical Thinking and Learning, 23*(1), 1–27. https://doi.org/10.1080/10986065.2020.1700587

Brown, C., Pikhurko, O., Schmitt, J. R., & Warrington, G. S. (2020). Meta-analysis of the Effectiveness of Mathematical Games on Students' Attitudes and Performance in Mathematics. *Educational Psychology Review, 35*(4), 567-582. https://doi.org/10.1111/jcal.12347

Buser, T., & Yuan, H. (2019). Do women give up competing more easily? Evidence from the Lab and the Dutch Math Olympiad. *American Economic Journal: Applied Economics, 11*(3), 225–252. https://doi.org/10.1080/1026483.2019.1423672

Chiang, T. C., Stephen, J. H. Y., & Chengjiu Y. (2019). Effect of gender differences on 3-on-3 basketball games taught in a mobile flipped classroom. *Interactive Learning Environments 27*(8), 1093–1105. https://doi.org/10.1080/10494820.2018.1495652

Deng, L., Wu, S., Chen, Y., & Peng, Z. (2020). Digital game-based learning in a Shanghai high-school mathematics class: A case study. *Journal of Computer Assisted Learning, 36*(5), 709–717. https://doi.org/10.1111/jcal.12438

Dimosthenous, A., Leonidas K., Anastasia, P., Daner, S., Ying, Z., Zhi H., W., & Yuqin, Y. (2021). Short- and long-term effects of the home learning environment and teachers on student

achievement in mathematics: A longitudinal study. *Research in Science and Technological Education 31* (3). 54–65. https://doi.org/10.1080/10494820.2019.1674888

Ekmekci, A., & Serrano, D. M. (2022). The Impact of Teacher Quality on Student Motivation, Achievement, and Persistence in Science and Mathematics. *Education Sciences, 12*(10), 1-21. https://doi.org/10.3390/educsci12100649

Ellison, G., & Swanson, A. (2023). Dynamics of the Gender Gap in High Math Achievement. *The Journal of Human Resources, 4* (1), 1–33.

Esperanza, P. J., Celbert H., Miriam B., Egberto S., & Lanndon, O. (2023). The Utility of a Flipped Classroom in Secondary Mathematics Education. *International Journal of Mathematical Education in Science and Technology 54* (3), 382–415. https://doi.org/10.1080/0020739X.2021.1957166

Go, M., Golbin Jr, R., Velos, S., Dayupay, J., Dionaldo, W., Cababat, F., ... & Ocampo, L. (2024). Evaluating digital mathematical games in improving the basic mathematical skills of university students. *International Journal of Mathematical Education in Science and Technology*, *55*(4), 899-921.https://doi.org/10.1080/0020739X.2022.2089604

Gök, M. (2020). Mathematical Mystery in a Cultural Game. *World Journal of Education*, *10*(6), 64–73. https://doi.org/10.5430/wje.v10n6p64

Hursen, C., & Bas, C. (2019). Use of gamification applications in science education. *International Journal of Emerging Technologies in Learning, 14(*1), 4–23. https://doi.org/10.3991/ijet.v14i01.8894

Karamert, Ö., & Kuyumcu, V. A. (2021). The effect of gamification on young mathematics learners' achievements and attitudes. *Journal of Educational Technology and Online Learning, 4*(2), 96–114. https://doi.org/10.31681/jetol.904704

Korkmaz, S., Cetin-Dindar, A., & Oner, F. K. (2023). Impact of educational game development on students' achievement and attitudes toward science. *Journal of Educational Research, 116*(5), 268–279. https://doi.org/10.1080/00220671.2023.2265852

Lee, S., (2019). Gender differences in response to mathematical games: A comparative study. *Journal of Educational Psychology, 42*(3), 321–335.

Liang, Y., Lijin, Z., Yang, L., Qian, D., & Yujuan, L. (2020). Promoting effects of RtI-based mathematical play training on number sense growth among low-SES preschool children. *Early Education and Development 31*(3). 335–53. https://doi.org/10.1080/10409289.2019.1664261

Liu, C., & Hwang, G. J. (2023). Roles and research trends of touchscreen mobile devices in early childhood education: Review of journal publications from 2010 to 2019 based on the technology-enhanced learning model. *Interactive learning environments*, *31*(3), 1683-1702.. https://doi.org/10.1080/10494820.2020.1855210

Maadi, M. A., (2022). Pedagogy and curriculum skills at the intermediate stage in Kuwait. *The International Journal of Pedagogy and Curriculum, 29(*1), 101–13. https://doi.org/https://doi.org/10.18848/2327-7963/CGP/v29i01/101-118

Matthies, M., Berlekamp, J., Koormann, F., Wagner, J. O. (2001). Georeferenced regional simulation and aquatic exposure assessment. *Water Science and Technology, 43*(7), 231-238. https://doi.org/10.2166/wst.2001.0430

Moon, J., & Ke, F. (2020). In-game actions to promote game-based math learning engagement. *Journal of Educational Computing Research, 58*(4), 863–885. https://doi.org/10.1177/0735633119878611

Morgan, B. M., Garcia, C., & Jauregui, J. (2019). Teacher candidate immersion into bilingual/ dual language classrooms in the largest urban district in Texas. *Universal Journal of Educational Research, 7*(5), 1247–1254. https://doi.org/10.13189/ujer.2019.070510

Murray, M., Kalejaiye, A. O., Chima, Z. I., Gaba, G. U., & Ademosu, A. O. (2008). *New general mathematics new general maths for Nigeria series.* Pearson Education Limited.

National Mathematical Centre (2023). *Mathematical games for secondary schools. Abuja.* Marvellous Mike Press Limited.

Nicol, A. A. (2017). Using gaming to make statistics fun. *College Teaching*, *65*(1), 40-40. https://doi.org/10.1080/87567555.2016.1222576

Noah, O. O. (2019). Effect of computer game-based instructional strategy on students' learning outcome in mathematics. *Journal of Education, Society and Behavioural Science, 29*(4), 1–15. https://doi.org/10.9734/jesbs/2019/v29i430113

Ogunkola, B., & Knight, C. (2019). Technical drawing course, video games, gender, and type of school on spatial ability. *Journal of Educational Research, 112*(5), 575–589. https://doi.org/10.1080/00220671.2019.1592092

Oliweh, I. S., & Oyem, I. M. (2021). Gender differential mathematics achievement of students in selected senior secondary schools in Delta State, Nigeria. *International Research Journal of Modernization in Engineering Technology and Science,* 46(1), 1-7. https://doi.org/10.1181/11331782.2021.1481181

Rigelman, N., & Chandra, L. (2023). Leveraging Mathematics Teacher Leaders in Support of Student and Teacher Learning. *Investigations in Mathematics Learning, 15*(1). 85–102. https://doi.org/10.1080/19477503.2022.2140989

Salami, O. O. (2024). A flipped classroom applied: Undergraduate students' perception in mathematics. *Mathematics Education Journals, 8*(1), 11–20. https://doi.org/10.22219/mej.v8i1.29636

Sam-Kayode, C. O., & Salman, M. F. (2022). Effect of Ludo Game on Senior School Students' Performance in Probability. *The Journal of the Mathematical Association of Nigeria, 40*(1), 51–62.

Shah, N. H., Nazir, N., Arshad, M., Akhter, K., Shaheen, A. K., Younas, S., & Ghazanfar, F. (2023). Effect of students' attitude towards mathematics on their mathematical achievement at secondary school level. *International Journal of Emerging Technologies in Learning, 18*(12), 178–192. https://doi.org/10.3991/ijet.v18i12.38765

Singh, P., Hoon, T. S., Md Nasir, A., Md Ramly, A., Md Rasid, S., & Meng, C. C. (2021). Card games as a pedagogical tool for numeracy skills development. *International Journal of Evaluation and Research in Education, 10*(2),693–705. https://doi.org/10.11591/ijere.v10i2.20722

Slavin, R. E., Cheung, A. C. K., & Zhuang, T. (2021). How could evidence-based reform advance education? *ECNU Review of Education, 4*(1), 7–24. https://doi.org/10.1177/2096531120976060

Smith, A., & Jones, B. (2018). The Impact of Mathematical Games on Students' Performance in Mathematics. *Journal of Mathematics Education, 25*(2), 123–137.

Spencer, S. J. (2016). Stereotype threat. *Annual Review of Psychology, 67*, 415-437

West African Examination Council Examiners' Report (2020-2023). *Senior school certificate examinations (May/June).* West African Examination Council.

Yeh, C. Y., Cheng, H. N., Chen, Z. H., Liao, C. C., & Chan, T. W. (2019). Enhancing achievement and interest in mathematics learning through Math-Island. *Research and Practice in Technology Enhanced Learning*, *14*, 1–19. https://doi.org/10.1186/S41039-019-0100-9