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Sustaining Retentive Memory of Mathematics Concepts in Adolescents Utilising Game-Based Learning: A Case of Repeated Measures

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Abstract. Effective mathematics education is pivotal for students' academic achievements and future career prospects. However, traditional teaching methods are often inadequate for helping students retain mathematical concepts, emphasizing the necessity for innovative approaches such as game-based learning. This research aimed to assess the efficacy of game-based learning in bolstering the retention of trigonometry concepts among senior secondary school students. Employing a mixed between and within measures ANOVA design, the study randomly assigned 60 students (aged 15-16 years, 31 males and 29 females) to either an experimental group (n=28) receiving game-based learning or a control group (n=32) receiving traditional instruction. Data, collected through the study's tool (Mathematics Achievement Test [MAT]) at the pre-test, post-test, and retention test stages, underwent repeated measures ANOVA analysis. Results indicated significant effects of Group [$F(1, 58) = 44.081$, $p<.001$, $\eta^2p=.432$], Time [$F(1.783, 103.4) = 16.561$, $p<.001$, $\eta^2p=.222$], and Group by Time interaction [$F(1.783, 103.4) = 18.125$, $p<.001$, $\eta^2p=.238$]. The experimental group exhibited notably higher retention scores (Time 3 mean = 74.82) than the control group (Time 3 mean = 44.38). Importantly, gender, age, and location did not significantly moderate the effectiveness of the game-based approach. In conclusion, game-based learning effectively enhances and sustains students' retention of trigonometry concepts, irrespective of demographic variables. This study furnishes empirical validation for integrating game-based learning into mathematics education, underscoring its potential to fortify conceptual retention, and offering actionable insights for educators and policymakers alike.

Keywords: age; game-based learning; gender; location; students' retention in mathematics

1. Introduction

Pursuing scientific knowledge has led to numerous discoveries and innovations, such as advanced communication and transportation systems, making the world a global village (Mobolaji, 2017). These technological advancements rely heavily on a solid mathematical foundation as scientific knowledge would be incomplete without it. For meaningful progress to occur globally, a strong base in science and mathematics is essential. Mathematics holds various meanings in contemporary times. According to Aminu and Akinmeji (2022), mathematics reflects a person's subconscious and mental processes. It is further explained as the field that employs precise, logical, exact, and simple mental processes to enhance human comprehension of itself and its surroundings (Egara & Mosimege, 2024a; Okeke et al., 2022). The term "mathematics" originates from the Greek word for "learned things," referring to the science of measurement, calculation, and object description (Nzeadibe et al., 2019, 2020). Suleiman and Hammed (2019) argue that a nation cannot become wealthy or economically independent without studying mathematics, as science and technology are built upon it. Mathematics acts as a bridge between mathematical and non-mathematical information, underscoring its significance. Consequently, mathematics is a core component of elementary and secondary school curricula and a prerequisite for admission to higher education programmes (Aminu, 2018; Mosimege et al., 2024).

The National Policy on Education recognises the importance of instilling permanent literacy and numeracy in students. The policy outlines the general goals of primary and secondary education, which also include the creation of a lifelong appreciation of reading, writing, and numeracy skills, the development of excellent communication skills, and the establishment of a strong foundation for critical and analytical thinking (Federal Republic of Nigeria, 2013). In fact, without mathematics, no country can attain widespread numeracy and scientific thinking. However, even though mathematics is important, many students struggle with internal and external examinations (Osakwe et al., 2023).

Mathematicians have identified numerous factors influencing students' poor achievement and retention in mathematics. These include inadequate primary school mathematics instruction (Uka & Ezeh, 2022), overcrowded classrooms with outdated resources (Evans et al., 2019), and anxiety surrounding mathematics (Egara & Mosimege, 2024b; Nzeadibe et al., 2023; Okeke et al., 2023; Sarfo et al., 2020, 2022; Terry et al., 2023). Issues such as teachers' methods and attitudes in mathematics classes (Jameel & Ali, 2016), student lack of motivation and negative attitude (Sule, 2017; Wachira, 2016), and ineffective mathematics teaching strategies (Egara & Mosimege, 2023a, 2023b; Okeke et al., 2023; Osakwe et al., 2023) also significantly impact learning outcomes. Furthermore, the challenge of students retaining mathematical concepts is widely acknowledged in the literature (Nzeadibe et al., 2020). This research is particularly concerned with understanding how ineffective teaching approaches contribute to students' difficulties in retaining mathematical concepts, alongside these broader educational challenges. However, mathematics researchers have sought appropriate methods of teaching mathematics concepts over the years to increase students' performance and retention in the subject. Using games to learn is a recommended approach to teaching mathematics (Beşaltı & Kul, 2021; Karakoç et al., 2022; White & McCoy, 2019).

Game-based learning defines and promotes learning goals by utilising the power of games as a teaching tool. Game-based learning goes beyond mere gameplay; it involves educational activities designed to introduce concepts progressively and guide users towards specific learning objectives (Pho & Dinscore, 2015). This approach utilizes instructional games that incorporate elements such as engagement, immediate rewards, and friendly competition, all aimed at sustaining learners' motivation in academic settings. Game-based learning benefits all students from pre-school to post-secondary education, which is a significant development. Additionally, it is irrelevant where or how students learn; they can do so either individually or in groups while using physical items or online games (Nisbet, 2023).

Nisbet (2023) lists a few of the most typical game-based learning examples, such as card games, which use a standard or game-specific deck of cards. Board games, which involve moving components or pieces, are frequently used. Chess and Checkers are the two most well-known board games; however, students can find hundreds, if not thousands, of others to explore (this study utilised the board games). Simulation games are games that closely replicate real-world actions. The Sims, a popular life simulation game brand that lets users create and explore virtual worlds, made its debut in 2000. Word games are usually interactive media to investigate linguistic principles or language proficiency. A classic word game is Scrabble, whereas a more contemporary one is the programme Words With Friends. Puzzle games are games that place a strong focus on using logic, word completion, sequence solving, spatial awareness, and pattern recognition to solve puzzles. For instance, the mathematics games Sudoku and 2048 are well-liked. Video games are electronic games that allow players to control what shows on the screen using a joystick, controller, or keyboard. The venerable Pac-Man or, more recently, Fortnite, are two examples that might come to mind. Role-playing games are where participants take on the roles of fictional characters who go on journeys.

Playing educational games can help us re-evaluate our learning processes. This allows the students to produce their materials, exchange instructional insights, and hone their abilities in preparation for the actual reality (Karakoç et al., 2022). Games encourage learning involvement on the levels of cognition, affect, and sociocultural, in contrast to other forms of media that do not provide a fun learning method (Plass et al., 2015). Through exchanges between learners and the game, learners and other learners, and learners and instructors, as well as through meaningful feedback, game-based learning promotes the collaborative building of knowledge (Vlachopoulos & Makri, 2017). Compared to traditional instruction methods, a study has shown that educational games increase students' high-level thinking skills and motivation (Sezgin, 2016). Additionally, evidence supports the idea that game-based learning can successfully present lessons in an impressive and inspiring way, increasing learners' interest in STEM subjects and raising their academic accomplishment (Musselman, 2014).

Despite the benefits of game-based learning, there are some limitations. Game-based learning may take up a great deal of time, and it can be challenging to anticipate how long each game session will last (Boghian et al., 2019). Additionally, some students may feel uneasy about competition, visibility, and comparison of game outcomes (Jääskä & Aaltonen, 2022). Gamified courses may be perceived as demanding by students, who may instead favour more conventional learning techniques (Domínguez et al., 2013). Learners may become frustrated by improper technical game-based learning applications or a disconnect from learning goals (Shute et al., 2015). However, during game-based learning sessions, mild confusion and irritation may promote learning and generate positive affective states such as delight and exhilaration (Jääskä & Aaltonen, 2022). Molin (2017) summarises the challenges to implementing and embracing game-based learning. They include difficulty selecting and integrating educational games, teachers' lack of time to plan gameplay sessions and inadequate technical ability. Teachers may be hesitant to use the approach owing to concerns about integrating game-based learning into curricula, time constraints in the classroom, and the novelty of game-based learning teaching techniques (Jong, 2016).

The social learning theory, created by Albert Bandura in 1930, is used in the current study. The theory's tenets include (a) Attention: Without concentrating on the task, learners cannot learn. Learners are more likely to pay attention to something new or unusual when presented, which will aid their learning; (b) Retention: Learning occurs when knowledge is internalised. Then, when it is time to react to a situation, learners can remember that learned knowledge; (c) Reproduction: When necessary, learners repeat the knowledge or behaviour they have previously acquired. How they react can be improved by mentally practising or acting it out; and (d) Motivation: This is necessary for any task to be completed. Usually motivation comes from witnessing someone else being rewarded or punished for their actions. This might motivate learners to behave in the same way or not. The social learning theory, as conceptualized by Bandura, asserts that individuals learn social behaviours by observing and emulating the actions of others. According to social learning theories, a social environment is essential for learning to occur. The theory, which encourages social interaction among peers, asserts that playing games with peers would promote learning among peers and serve as the foundation for the present investigation. Through participation in classroom games or contests, students can focus on learning through observation, imitation, and interaction. This might aid their retention of the information acquired in the classroom to the point where they can reproduce it, which might result in improved performance in mathematics.

2. Reviewed Studies

Several studies have been conducted in various contexts on the effectiveness of game-based approach in different academic disciplines as well as its impact on students' retention, both internationally and locally.

2.1 Effectiveness of Game-Based Learning across Disciplines
Vu et al. (2022) studied the efficacy of word games in improving vocabulary retention in grade 7 EFL classes in South Vietnam. They found that students who had been learning vocabulary through word games retained a higher percentage of their vocabulary than those in the control group. Similarly, Selvi and Çoşan (2018) examined the impact of instructional games on learners in Turkey learning about the Kingdoms of Living Things. Their results showed that students taught using educational games outperformed their peers in the control group regarding achievement and retention of new information in biology.

2.2 Game-Based Learning in Mathematics
Omeodu and Fredrick (2020) investigated the impact of a game-based teaching strategy on SS1 students' retention of algebra in Imo State, Nigeria. The researchers found that students who had been taught algebra through games had better memory retention rates than those who had not, with no significant differences in retention between male and female students. Similarly, Bahrami et al. (2012) compared the effectiveness of game-based and traditional teaching methods in grade 1 mathematics concepts in Iran, showing that students using game-based learning retained mathematics ideas better than their counterparts in the traditional setup. Alizadehjamal and Langari (2021) found that grade 3 elementary female students in Iran retained mathematics concepts more readily when taught through games. These studies underscore the potential of game-based learning to improve retention in mathematics. Our study extends this by focusing on trigonometry, a critical yet challenging topic for many students.

2.3 Influence of Demographic Factors
Omeodu and Fredrick (2020) found no significant gender differences in retention with game-based learning, whereas Alizadehjamal and Langari (2021) reported higher retention rates among female students. This highlights mixed results regarding gender differences in game-based learning outcomes. Our study further investigates the combined influence of gender, age, and location on the effectiveness of game-based learning, providing a comprehensive understanding of these demographic factors.

2.4 Design and Validity Considerations in Game-Based Learning Research
Many reviewed studies, including those by Alizadehjamal and Langari (2021), Bahrami et al. (2012), and Omeodu and Fredrick (2020), utilised quasi-experimental designs. While these studies provided valuable insights, they were limited by potential biases inherent in quasi-experimental methods. Our research addresses this limitation by employing a true experimental design with repeated measures, enhancing the scientific validity of our findings.

2.5 Addressing Research Gaps
Despite the promising findings, there is a notable gap in research focusing on the long-term retention of mathematics concepts through game-based learning, particularly in specific regions such as Enugu State, Nigeria. Existing studies have not sufficiently explored the sustained impact of this approach over time. Our research seeks to fill this gap by investigating the long-term retention of trigonometry concepts among senior secondary school students in Enugu State.

By providing empirical evidence on the sustained effectiveness of game-based learning, we aim to offer practical insights for educators and policymakers.

2.6 Connecting Reviewed Studies to Current Research

Traditional mathematics teaching methods often fail to engage students effectively, leading to poor retention of mathematical concepts. While game-based learning has shown promise in enhancing student motivation and understanding in various subjects globally, its impact on the long-term retention of mathematics concepts, particularly trigonometry, remains under-researched, especially in Enugu State, Nigeria. Previous studies have often used quasi-experimental designs, whereas this study employs a true experimental design with repeated measures, providing higher scientific validity. Although some research has examined the influence of gender, age, and location independently, no study has investigated their combined influence on the efficacy of game-based learning in enhancing students' retention of mathematics concepts.

This study seeks to address these gaps by offering empirical evidence on how game-based learning can effectively improve and sustain the retention of trigonometry concepts among diverse student populations in Enugu State, Nigeria. By evaluating whether the game-based learning approach can significantly improve and sustain the retention of trigonometry concepts among senior secondary school students, regardless of gender, age, or location, this study aims to offer valuable insights for educators and policymakers to upgrade mathematics instruction and student outcomes. Therefore, the study's questions that guided this research were as follows: What are the mean retention scores of learners exposed to the game-based learning approach? What is the influence of gender, age, and location on the effectiveness of game-based learning in enhancing students' retention of mathematics concepts? Consequently, the hypotheses formulated for the study were: Ho1: The game-based learning approach does not significantly impact students' mathematics retention. Ho2: Gender, age, and location do not significantly moderate the effectiveness of game-based learning in enhancing students' retention of mathematics concepts.

3. Methodology

3.1 Research Design

This study employed a mixed-between and within measures analysis of variance (ANOVA) design. The researchers specifically used the design to determine whether the game-based learning approach impacted students' mathematics retention within and between the experimental and control groups.

3.2 Participants

Sixty students from senior secondary school level two (SS 2), with 31 males and 29 females, aged between 15 and 16 years, were chosen to take part in the study. The study's sample size was formed utilising the G*Power software version 3.1 (Faul et al., 2007) and suggested a sample size of 56 participants following these parameters: alpha (α =.05), effect size f = 0.25, power ($1-\beta$ =.80), and statistical test (F tests Analysis of Variance [ANOVA]: Repeated measures, between factors). Two public secondary schools, one in an urban and the other in a rural area, were selected randomly from the 16 public secondary schools in Enugu State's Udenu Local Government Area with SS 2 students' population of 3,831 (Post Primary School Management Board, 2022). Participants in this current study were recruited from the schools chosen based on their trigonometry performance in mathematics assessment conducted by their regular mathematics teachers before the investigation. Students with grades ≤50 were enlisted to participate in the study. In this study, a simple randomization procedure was employed to allocate students to the intervention groups (experimental and control). The use of a computer-generated random list, as suggested by Saghaei (2004), resulted in 28 students being assigned to the experimental (game-based learning) group and 32 to the control (conventional) group (see Figure 1 below for participants' eligibility criteria and sampling distribution for the study). Participants in the control group were also given the opportunity to experience the game-based learning programme at a later time. The ages of students in the experimental (game-based learning) group (1.68 ±.48) were not significantly different from the ages of learners in the control group (1.63 ±.49; t(58) = -.427, p =.671). Additional information about the students can be found in Table 1.

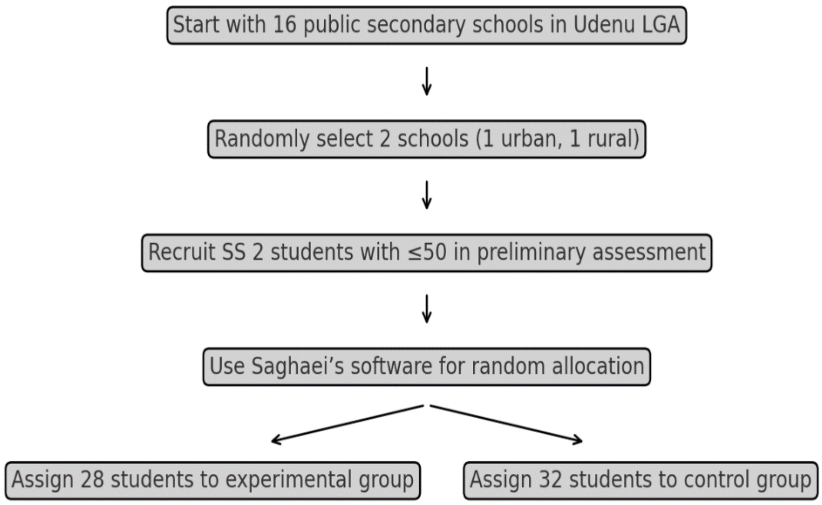

Figure 1: Participant eligibility criteria and sampling distribution

Table 1: Demographic characteristics of the participants (within-group analysis)

Characteristic dimension	Experimental group, n (%)	Control group, n (%)	x^2	Significance
Gender				
Male	14 (45.2%)	17 (54.8%)	.058	.809
Female	14 (48.3%)	15 (51.7%)		
Age				
14-15 years	9 (42.9%)	12 (57.1%)		
	1.68 ± .48	*1.63 ± .49*	*-.427(*df*=58)	.671
16-17 years	19 (48.7%)	20 (51.3%)		
School location				
Urban	15 (46.9%)	17 (53.1%)	.001	.972
Rural	13 (46.4%)	15 (53.6%)		

Note. n represents number of participants; x^2: chi-square. *t-test value

3.3 Measure

The Mathematics Achievement Test (MAT), which the researchers created, was utilised to gather data. The MAT covers trigonometric functions' concepts and their degree values (sin, cos, tan, cot, cosec and sec). Students must/had to select the correct response to each of the 20 questions on the MAT, which has alternatives A, B, C and D. The mathematics scheme of work or curriculum for senior secondary school two was used to develop the MAT questions. Any correct response earned five marks, indicating that the lowest and highest possible scores were 0 and 100, respectively. This means that the MAT's 20 questions had a highest score of 100 and a lowest score of 0.

3.4 Validity and Reliability of the Measure

The MAT was validated by three research professionals, including one measurement and evaluation expert and two mathematics education experts. The MAT items were given to the experts to evaluate regarding phrasing, suitability for the study's objective, quality, and language used. The validation judgements made by the experts led to changes in the MAT. In addition, a table of specifications or test blueprints that the experts validated was used to guarantee the content validity of the MAT. A specification table is a two-dimensional representation showing how educational content aligns with various cognitive levels identified in Bloom's classification of educational goals. In constructing the 20-item MAT, themes and cognitive domain levels were organized into rows and columns, respectively. Each level and content within the cognitive domain received specific percentage weights. The percentage weights for each concept and the cognitive domain level determined the number of MAT items. The aim of this exercise was to verify that the MAT sufficiently covered the intended instructional topic. Furthermore, copies were given to a similar sample of SS 2 students in a different area in order to assess the MAT's internal consistency dependability. This was done to determine how reliable the items were. The data gathered from the administration of the pilot testing was examined utilising the Kuder-Richardson formula 20, which produced an internal consistency reliability index of 0.81. The temporal consistency of the assessment was determined by administering the additional MAT measure two weeks after the initial assessment. Using Pearson correlation, the data from the two administrations were analysed, and the result was an index of 0.85.

3.5 Procedure

Before the study began on 13 October 2022, it received authorization from the PPSMB in Enugu State's Udenu Zonal office, under reference number REC/PPSMB/22/00354. The researchers visited the institutions involved in the study to obtain permission formally from the school heads before starting the investigation. The school heads approved the investigation. The parents, students, and instructors consented to participate as they were provided with informed consent forms to complete and sign to confirm their consent to participate. The study employed the regular mathematics teachers at the selected institutions as research assistants. The researchers conducted a one-week training programme to equip these instructors with the skills to apply and teach trigonometry concepts (trigonometric functions and their values in degree [sin, cos, tan, cot, cosec and sec]) through a game-based learning methodology. The mathematics instructors in the game-based learning (experimental) group and the conventional (control) group were provided with lesson plans and notes as a resource. The lesson plan for the experimental group was designed based on game-based learning, which incorporated activities involving the Hand Trick Game and the Trig-Conquest board game developed by Dueñas et al. (2021). The lesson plan for the control group was developed using a traditional approach. Prior to commencing the actual intervention, the SS 2 students completed a pre-MAT assessment (Time 1). The intervention itself was conducted over four weeks, followed by the administration of the post-MAT in the fifth week (Time 2). Prior to administering the post-MAT, the pre-MAT items were reorganized to provide a new appearance without altering their substance. The post-test results were recorded and used to report on learners' accomplishment on the mathematics concepts, analyzed by gender and treatment group. Four weeks later, the post-MAT items were also rearranged before the post-post-test (retention) (Time 3). Data on students' retention, categorized by gender and treatment group, was put together based on the post-post-MAT findings.

3.6 Addressing Internal Validity

Several measures were taken to mitigate potential threats to the internal validity of the study. The random assignment of students to experimental and control groups helped control for selection bias. To address maturation, the study duration was kept short (four weeks of intervention), minimising the likelihood of significant developmental changes. Testing effects were mitigated by rearranging the test items for each administration to prevent students from simply recalling answers from previous tests. Consistent use of the same validated and reliable MAT minimised instrumentation threats. To counter experimental mortality, all participants who started the study were encouraged to complete it, and their continued participation was monitored closely.

3.7 Data Analysis

The study utilized the Statistical Package for the Social Sciences (SPSS) version 28 to analyze the data. The analysis employed a 2 x 3 mixed-design approach, considering Group as a between-subjects factor and Time as a within-subjects factor. The study's research questions were addressed utilising the mean and standard deviation, and the hypothesis was evaluated through the F-test of repeated measures analysis of variance. Additionally, Mauchly's test of sphericity was not statistically significant, indicating that the repeated measurement assumption in the ANOVA was met (Mauchly $W = 0.879$, $p = 0.520$). In a repeated-measures ANOVA, sphericity is a critical assumption. As per standard practice, effect sizes are classified as small if they exceed 0.01, medium if they exceed 0.06, and large if they exceed 0.14 (Cohen, 1988).

Figure 2 below is a flowchart illustrating the research design and implementation. The flowchart visually represents the sequential steps of participant selection, random assignment, intervention implementation, and assessment phases. It offers a comprehensive view of the study's execution, thereby improving comprehension of the research methodology.

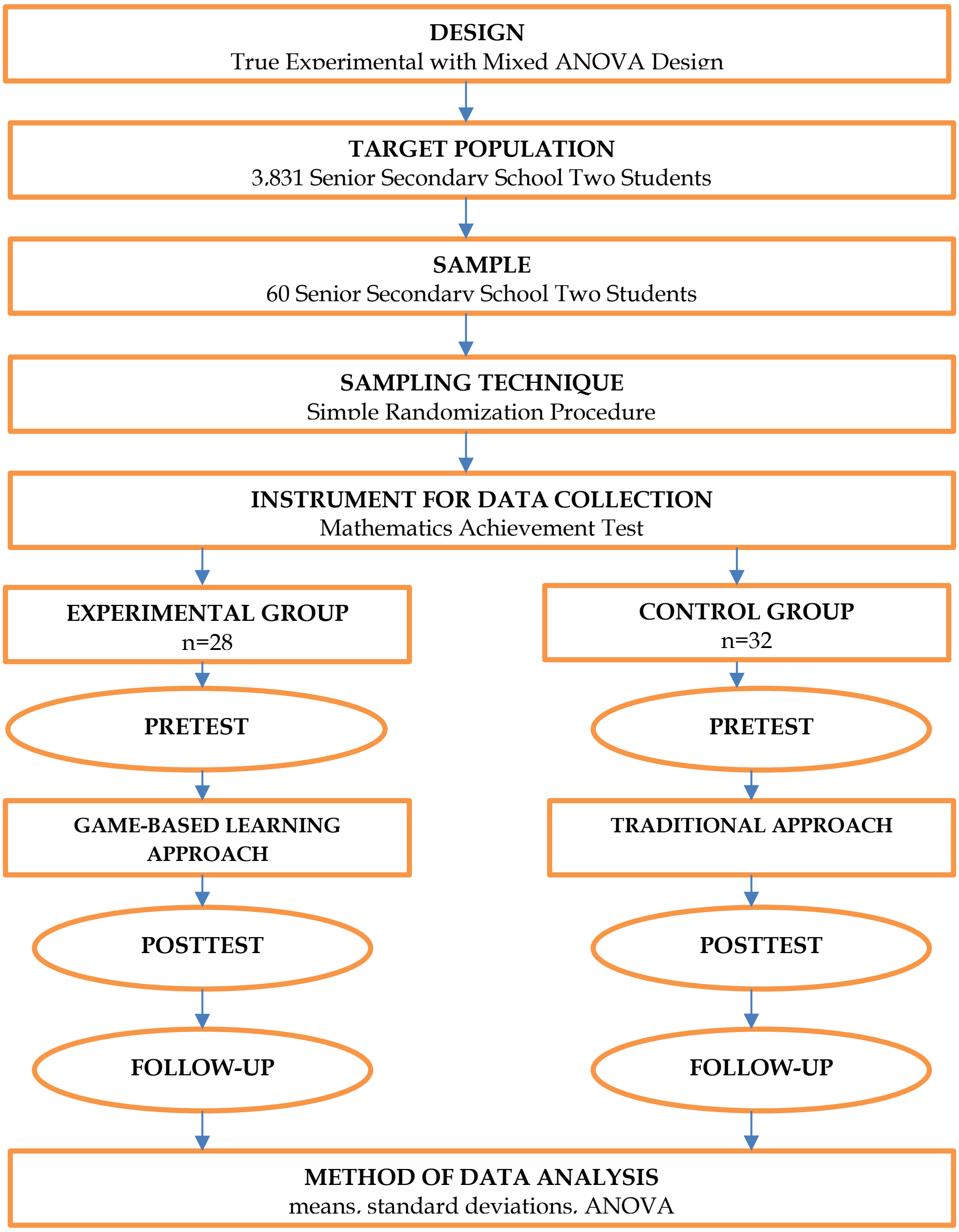

Figure 2: Research design and implementation

4. Results

The findings are organised based on the research questions and hypotheses.

Research question 1: What are the mean retention scores of students exposed to the game-based learning approach?

Table 2 indicates the learners who received the game-based learning intervention achieved a mean post-test score (Time 2) of 70.18 (*SD* = 0.18) and a mean retention score (Time 3) of 74.82 (*SD* = 13.84). In contrast, the students who received the conventional approach had a lower mean post-test score (Time 2) of 49.53 (*SD* = 14.72) and an even lower mean retention score (Time 3) of 44.38 (*SD* = 17.72).

Table 2: Results of repeated measures ANOVA for the study outcomes (effects of group, time, and time by group interaction)

Variables	Game-based		Control croup		rmAnova				
	M	*SD*	*M*	*SD*	Effect	*F*-ratio	*Df*	η_p^2	95%CI
MAT									
Time 1	46.61	15.28	46.88	17.77	G	44.081*	1, 58	.432	[42.43, 51.06]
Time 2	70.18	10.05	49.53	14.72	T	16.561*	1.783, 103.4	.222	[56.55, 63.16]
Time 3	74.82	13.84	44.38	17.72	G x T	18.125*	1.783, 103.4	.238	[55.45, 63.75]

Note. MAT: Mathematics Achievement Test; SD: standard deviation; CI: confidence interval; η_p^2: effect size. *p<.001

Hypothesis 1: The game-based learning approach does not significantly impact students' mathematics retention.

The findings indicated a significant impact of the Group (G) on secondary students' retention of mathematics knowledge (Greenhouse-Geisser corrected) [$F(1, 58) = 44.081$, $p < .001$, $\eta 2p$=.432], Time (T) [$F(1.783, 103.4) = 16.561$, p<.001, η2p=.222], and Group by Time interaction (G x T) [$F(1.783, 103.4) = 18.125$, p<.001, $\eta 2p$=.238] (see Figure 3). The retention analysis (univariate analysis) findings demonstrated that the game-based learning intervention maintained its positive impact on the mathematics retention scores of the secondary school students in the experimental group [$F(1, 55) = 17.717$, p<.001, $\eta 2p$=.556, =.523]. Therefore, the hypothesis is rejected.

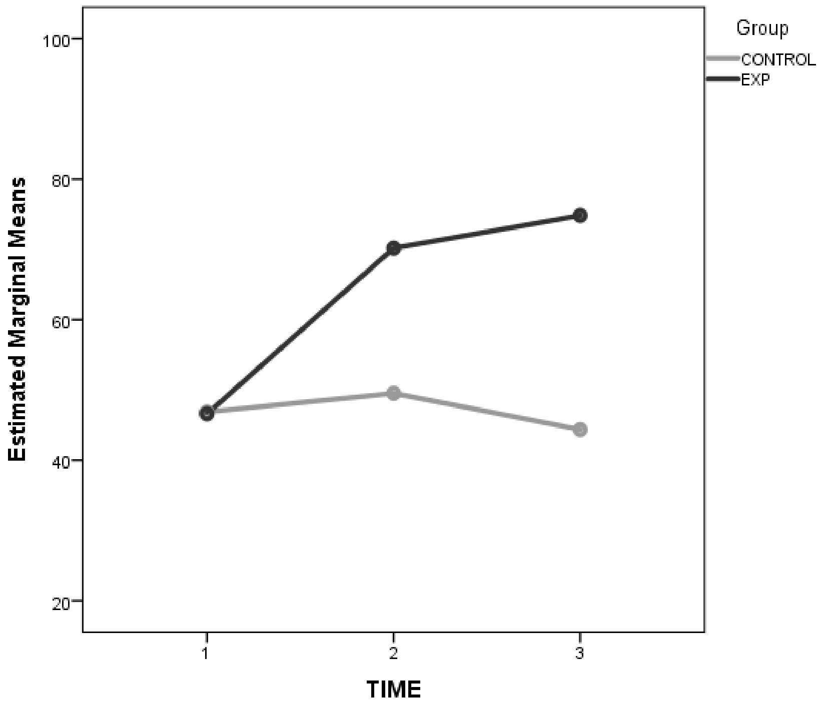

Figure 3: Time × group interaction effect

Research question 2: What is the influence of gender, age, and location on the effectiveness of game-based learning in enhancing students' retention of mathematics concepts?

Table 3: Analysis of the influence of moderator variables

Group	Moderator variable	N	Mean	SD. Dev.
Game-based learning approach group	*Gender*			
	Male	17	66.43	9.89
	Female	15	48.67	10.43
	Age			
	14-15 years	9	68.33	9.01
	16-17 years	19	71.05	10.62
	Location			
	Urban	15	68.67	9.72
	Rural	13	71.92	10.52

The outcome of the analysis in Table 3 indicated that the gender of participants exposed to the game-based learning approach indicates that male learners had a retention mean score of 66.43 (*SD* = 9.89) compared to their female counterparts, who had a retention mean score of 48.67 (*SD* = 10.43). On the other hand, the table also revealed the age of participants exposed to the game-based learning approach, which indicates that students between the ages of 14-15 years had a retention mean score of 68.33 (*SD* = 9.01) compared to their counterparts who are between the ages of 16 -17 years that had a retention mean score of 71.05 (*SD* = 10.62). Lastly, the table revealed that the location of participants exposed to the game-based learning approach indicates that urban students had a retention mean score of 68.67 (*SD* = 9.72) compared to their rural counterparts, who had a retention mean score of 77.92 (*SD* = 10.52).

Hypothesis 2: Gender, age, and location do not significantly moderate the effectiveness of game-based learning in enhancing students' retention of mathematics concepts.

Table 4: Analysis of variance of the significant influence of the moderator variables

Source	Type III sum of squares	df	Mean square	F	Sig.	Partial eta squared
Corrected model	8001.047[a]	15	533.403	3.006	.002	.506
Intercept	18597.319	1	18597.319	104.810	.000	.704
PreMAT	.095	1	.095	.001	.982	.000
Group	5040.322	1	5040.322	28.406	.000	.392
Gender	100.867	1	100.867	.568	.455	.013
Age	380.548	1	380.548	2.145	.150	.046
Location	123.104	1	123.104	.694	.409	.016
Error	7807.286	44	177.438			
Total	225850.000	60				
Corrected total	15808.333	59				

a. R Squared = .506 (Adjusted R Squared = .338)

The analysis in Table 4 showed that the moderating variables (Gender, Age, and Location) did not significantly affect the impact of game-based learning on improving and sustaining learners' retention of mathematics knowledge [$F(1, 44) = .568$, $p>.001$; $F(1, 44) = 2.145$, $p>.001$; $F(1, 44) = .694$, $p>.001$]. Therefore, the hypothesis is not rejected.

5. Discussion

This study sought to evaluate the effectiveness of the game-based learning strategy in enhancing and maintaining students' retention of mathematical concepts. The findings revealed that learners who learned mathematics through the game-based strategy retained the information more effectively than those taught using traditional methods. Furthermore, the test of the first hypothesis confirmed that learners in the experimental group sustained their retention of mathematics concepts better than those in the control group. Thus, it can be said that the use of games in the classroom improved and sustained the students' retention of the mathematical concepts. The fact that the students actively engaged in the learning process and interacted with one another may have contributed to this observable difference. The finding agrees with the results of Alizadehjamal and Langari (2021), Bahrami et al. (2012), and Omeodu and Fredrick (2020) who, in their various studies, revealed that the game-based learning effectively boosted students' retention of mathematics concepts.

The results also showed that the gender, age, and location of the participants did not significantly affect the effectiveness of the game-based learning in sustaining learners' retention in mathematics. This finding indicates that irrespective of gender, age, or location, the sustenance of students' retention in mathematics is at an equal level. The outcome of the no significant influence for gender could be that the game activities utilised positively influenced the mathematics instruction, which could have led both male and female students to retain and sustain the mathematics concepts. The male and female students could have also been actively involved in the game activities through their participation and interactions, leading to their retention of the mathematics concepts. The finding corroborates with the result of Omeodu and Fredrick (2020), who found that no differences exist between male and female students' retention of mathematics when the game-based teaching method is used. Again, our finding also validates the result of research by Alizadehjamal and Langari (2021) that female students retained mathematics concepts more readily when the game-based learning approach was utilised.

Novelty: This study is novel in several ways. It is the first to employ a true experimental design with repeated measures to evaluate the impact of game-based learning on the retention of trigonometric concepts among senior secondary students in Enugu State, Nigeria. Additionally, unlike previous studies, this research considered the combined influence of gender, age, and location on the effectiveness of game-based learning. By demonstrating that these demographic factors do not significantly influence retention outcomes, this study offers robust evidence supporting the universal applicability of game-based learning strategies across diverse student populations. These insights contribute to educational practices and policies to enhance mathematics instruction and student performance.

6. Conclusion

Given that the game-based learning approach has shown positive results in mathematics retention with secondary school one (SS 1) students in Imo State, Nigeria (Omeodu & Fredrick, 2020) and primary one and three (grade 1 & 3) students in Iran (Alizadehjamal & Langari, 2021; Bahrami et al., 2012), blended with our research with SS 2 learners in Enugu State, Nigeria, we therefore conclude that the game-based learning strategy is considered helpful for sustaining retentive memory of mathematics concepts in adolescents students. We also conclude that gender, age, or location have no influence on the effect of the game-based learning strategy in sustaining students' retention in mathematics.

The findings of this study have significant educational implications, particularly for mathematics instruction. The demonstrated effectiveness of game-based learning in enhancing and sustaining students' retention of trigonometry concepts suggests that incorporating such innovative approaches into the curriculum could lead to improved learning outcomes. Educators are encouraged to integrate game-based elements into their teaching strategies to make learning more engaging and interactive. The study also highlights that the positive effects of game-based learning are consistent across different demographic factors, including gender, age, and location. This suggests that game-based learning can be a universally effective tool, providing equal opportunities for all students to improve their understanding and retention of mathematical concepts. For policymakers, these findings offer empirical support for the adoption of game-based learning approaches in educational programmes. By promoting and funding the development and implementation of game-based learning tools, policymakers can contribute to enhancing the quality of mathematics education and, consequently, students' academic success and future career opportunities.

6.1 Strength of the Study

The current study empirically established the effectiveness of the game-based strategy in increasing and sustaining retentive memory of mathematics concepts, utilising a sample of SS 2 Nigerian secondary school learners in Enugu State. The study is the first of its kind to consider moderator variables (gender, age, and location), which did not influence the mathematics retention of students who were exposed to the game-based learning approach. The study is also the first to use repeated measures design to ascertain the effect of game-based learning strategy on participants' retention in mathematics as students were randomly assigned to groups, enabling the researchers to compare both within- and between-group factors.

6.2 Limitations

One limitation of this study is the unequal distribution of participants, with 28 students in the experimental group and 32 in the control group. This imbalance may influence the results, potentially affecting statistical power and generalizability. Unequal sample sizes can introduce bias, complicating the attribution of observed differences solely to the game-based learning intervention. Future studies should aim for equal sample sizes in both groups to ensure a more robust comparison. Employing statistical techniques such as matching or stratification could also help balance the groups. Despite this limitation, our findings offer valuable insights into the impact of game-based learning on students' retention of mathematics concepts. However, caution is advised in generalising these results, and further research with balanced sample sizes is recommended to validate the findings.

Another noteworthy limitation of this study is that only students in senior secondary two classes were included. Consequently, future research should investigate whether game-based learning effectively enhances the retention of mathematics concepts in other secondary year levels and evaluate the generalizability of our findings.

6.3 Recommendation

The following are the suggested recommendations based on our findings:

(i) To boost the sustenance of retentive memory of learners' mathematics concepts, mathematics teachers should incorporate the game-based learning approach in their math lessons, especially in the teaching of trigonometrical functions.

(ii) To support professional development, the government and relevant educational organisations should organise seminars and workshops on game-based learning for mathematics teachers.

(iii) Mathematics teachers should include and choose appropriate game activities in their lesson plans that are suitable to facilitate mathematics instructions, assist students in creating an entire, concrete memory model of the relevant mathematical concepts, and enable them to recall mathematics information learned easily.

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Appendix 1

MATHEMATICS ACHIEVEMENT TEST (MAT)

SECTION A: *PERSONAL INFORMATION OF RESPONDENT*

Student Identification (ID) Number: …………………………………………
Student's Gender: Male [ ] Female [ ]
Student's Location: Rural [ ] Urban [ ]

SECTION B:

Instruction: Answer all Questions

1. What is the sine of 30 degrees?
   A) 0
   B) 1/2
   C) √3/2
   D) 1
2. Find the value of cos(60°):
   A) 1/2
   B) √3/2
   C) 1
   D) 0
3. Calculate the tangent of 45 degrees:
   A) 1
   B) √3
   C) 0
   D) 1/√2
4. Determine the cotangent of 60 degrees:
   A) √3
   B) 1/√3
   C) √2
   D) 1
5. What is the cosecant of 30 degrees?
   A) 2
   B) 1
   C) √3/2
   D) 2/√3
6. Evaluate the secant of 60 degrees:
   A) 2
   B) √3/2
   C) 1/√2
   D) 1
7. Solve sin(90°):
   A) 0
   B) 1
   C) -1
   D) Undefined

8. Find cos(45°):
    A) 1
    B) √2/2
    C) 0
    D) -1
9. Determine the value of tan(180°):
    A) 1
    B) 0
    C) Undefined
    D) -1
10. What is the secant of 45 degrees?
    A) 1
    B) √2
    C) √3/2
    D) 1/√2
11. Calculate the value of sin(180°):
    A) 1
    B) 0
    C) -1
    D) Undefined
12. Find the cosine of 120 degrees:
    A) 1/2
    B) -1/2
    C) -√3/2
    D) √3/2
13. Determine the tangent of 30 degrees:
    A) 1/√3
    B) √3
    C) 1/√2
    D) 1
14. Evaluate the cotangent of 45 degrees:
    A) 1
    B) √2
    C) 1/√2
    D) -1
15. What is the cosecant of 60 degrees?
    A) 2/√3
    B) 1
    C) 2
    D) √3/2
16. Calculate the secant of 30 degrees:
    A) 2/√3
    B) 1/√3
    C) 2
    D) √3/2

17. Solve cos(90°):
    A) 1
    B) 0
    C) -1
    D) Undefined
18. Find the value of tan(45°):
    A) 1
    B) 0
    C) -1
    D) Undefined
19. Determine the value of cot(60°):
    A) 1
    B) √3
    C) 1/√3
    D) -1
20. What is the secant of 45 degrees?
    A) √2
    B) 1
    C) √3/2
    D) 1/√2

Mathematics Achievement Test (MAT) Answers:

1. B
2. B
3. D
4. B
5. D
6. A
7. B
8. B
9. B
10. B
11. B
12. C
13. A
14. B
15. D
16. C
17. B
18. A
19. C
20. A