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Fostering students' interest in trigonometry using game-based learning strategy: a case of repeated measures

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ABSTRACT

This study investigated the effectiveness of game-based learning in enhancing students' interest in trigonometry among secondary school students in Enugu State, Nigeria. The study addressed the need for increased engagement and interest in trigonometry by leveraging successful implementations of game-based learning from other educational contexts. A true experimental design with a repeated measures approach was employed, involving senior secondary two (SS 2) students randomly assigned to either the experimental or the control group. The experimental group received trigonometry instruction through game-based learning, while the control group followed traditional teaching methods. The data collection instrument was the trigonometry interest inventory (TII) used to assess students' interest levels at three points: pre-intervention, post-intervention, and follow-up. The repeated measures analysis of variance (ANOVA) was utilized to analyze changes in interest levels over time and between groups. The findings revealed two key findings: i) game-based learning significantly increased students' interest in trigonometry and ii) gender, age, and location did not significantly affect the effectiveness of the game-based learning approach in fostering students' interest in trigonometry. The study concludes that game-based learning effectively enhances students' interest in trigonometry, offering implications for educators to improve mathematics teaching practices through interactive and engaging strategies.

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1. INTRODUCTION

The pursuit of scientific knowledge has led to many discoveries and innovations, such as advanced communication and transportation systems, transforming the world into a global village [1]. These technological advancements are made possible by a solid foundation in mathematics. Without mathematics, scientific knowledge would lack the necessary structure and coherence, akin to a ghost without substance. Consequently, for deliberate and fruitful progress to occur globally, a solid basis in science and mathematics is essential. Mathematics has various interpretations in modern times. mathematics reflects a person's subconscious and mental processes, employing precise, logical, and simple mental procedures to enhance human comprehension of oneself and the immediate surroundings [2]. A nation's wealth and economic autonomy are intrinsically linked to its proficiency in mathematics, as science and technology are built upon this subject [3]. In general, mathematics serves as a bridge between mathematical and non-mathematical information. Due to its significance, mathematics is integrated into the curricula of elementary and secondary schools and prerequisite for admission to various programs and courses in higher education institutions [4].

The National Policy on Education in Nigeria underscores the importance of instilling permanent literacy and numeracy in students. This policy outlines the general goals of primary and secondary education, including the development of lifelong reading, writing, and numeracy skills, excellent communication abilities, and a strong foundation for critical and analytical thinking [5]. Mathematics is crucial for achieving widespread numeracy and scientific thinking, which are necessary for any country's advancement. Despite its importance, many students face difficulties with internal and external examinations in mathematics. These exams are often critical for academic progression and future opportunities, making this issue particularly concerning. Several factors contribute to students' struggles, including inadequate study habits, lack of confidence, and insufficient understanding of fundamental concepts. Addressing these challenges is essential to help students achieve better results and develop a positive attitude toward mathematics.

Researchers have identified several factors affecting students' poor achievement and retention in mathematics. Some of these factors include insufficient mathematics instruction in primary school [6]; crowded math classes and outdated math resources [7]; anxiety towards mathematics [8]; harsh teaching methods [9]; lack of student interest [10]; student laziness [11]; and poor teaching approaches adopted by math teachers [12]. Among these factors, the poor approach to teaching mathematics, which leads to students' lack of interest in the subject, is of particular interest to this research. Over the years, mathematics researchers have sought appropriate methods of teaching mathematics concepts that would increase students' performance and boost their interest in the subject. Game-based learning is one such recommended approach to teaching mathematics [13]–[15].

Game-based learning utilizes the engaging nature of games to achieve educational objectives. It emphasizes "learning through games rather than learning to play" [16]. This approach involves crafting educational activities that gradually introduce new concepts and guide learners towards a final goal, incorporating elements such as engagement, immediate rewards, and friendly competition. This approach maintains learners' academic motivation [16]. By integrating game elements such as rewards and competition, game-based learning aims to keep students engaged and interested in their studies. This method not only makes learning more enjoyable but also helps reinforce concepts through repetitive practice and instant feedback. As a result, students are more likely to stay motivated and committed to their academic goals. Game-based learning benefits students across all educational levels, from pre-school to post-secondary education, making it a highly inclusive approach. This inclusive strategy caters to diverse learning needs and preferences, making education accessible and enjoyable for everyone. It helps younger students build foundational skills in a fun and interactive way while providing older students with complex problem-solving and critical thinking exercises. The adaptability of game-based learning ensures its relevance and effectiveness across different educational levels and contexts. Additionally, it is irrelevant where or how students learn; they can do so individually or in groups, using physical items or online games [17].

Dimitra *et al.* [17] lists several common examples of game-based learning, 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, but students can explore hundreds, if not thousands, of others (this study utilized board games). Simulation games closely replicate real-world actions, with one of the most well-known life simulation game franchises being "The Sims", which debuted in 2000. Word games are interactive media used to investigate linguistic principles or language proficiency. Classic word games include Scrabble, while more contemporary examples are programmed like words with friends. Puzzle games emphasize logic, word completion, sequence solving, spatial awareness, and pattern recognition to solve puzzles. For instance, math games such as Sudoku and 2048 are well-liked. Video games are electronic games that allow players to control what appears on the screen using a joystick, controller, and keyboard. Classic examples include Pac-Man or, more recently, Fortnite. Role-playing games involve participants taking on the roles of fictional characters who go on journeys. These games often feature intricate storylines and require players to make decisions that affect the game's outcome. Role-playing games encourage creativity, strategic thinking, and teamwork as players collaborate to achieve common goals. They provide a safe environment for students to experiment with different scenarios and problem-solving approaches, beneficial for overall cognitive and social development.

Playing educational games allows students to re-evaluate their learning processes, produce their materials, exchange instructional insights, and hone their abilities for real-world application [14]. Games encourage learning involvement at cognitive, affective, and sociocultural levels, offering a fun learning method [18]. Through interactions between learners and the game, learners and peers, and learners and instructors, as well as through meaningful feedback, game-based learning promotes the collaborative building of knowledge [19]. Compared to traditional instruction methods, studies have shown that educational games enhance students' high-level thinking skills and motivation [20]. Furthermore, evidence supports the idea that game-based learning can effectively present lessons in an impressive and inspiring manner, increasing students' interest in science, technology, engineering, and mathematics (STEM) subjects and improving academic performance [14].

Although game-based learning has numerous benefits, it also presents certain challenges. The approach can be time-consuming, and it can be difficult to accurately predict the length of each gaming session [21]. Furthermore, some students might feel uneasy about the competitive nature, the public display of their performance, and the comparison with others [22]. Additionally, gamified courses might be perceived as more rigorous, causing some students to prefer conventional learning techniques [23]. Improper technical applications of game-based learning or a disconnect from learning goals can also frustrate learners [24]. However, mild confusion and irritation during game-based learning sessions can promote learning and generate positive affective states like delight and exhilaration [22]. The challenges to implementing and embracing game-based learning include difficulty selecting and integrating educational games, teachers' lack of time to plan gameplay sessions, and inadequate technical ability [23]. Teachers might be reluctant to use game-based learning because they worry about fitting it into their lesson plans, managing classroom time, and dealing with the unfamiliarity of these teaching methods [25].

The current study applies Bandura's social learning theory. The theory's tenets include attention, retention, reproduction, and motivation, which are essential for learning. Learners must concentrate on tasks to learn (attention), internalize knowledge for future use (retention), repeat acquired knowledge or behavior, when necessary (reproduction), and be motivated to complete tasks, often inspired by observing others' rewards or punishments (motivation). Social learning theory posits that people learn social behavior by observing and imitating others, with a social environment being crucial for learning. Playing games with peers in a classroom setting can enhance students' interest in learning through observation, imitation, and interaction, ultimately improving their performance in mathematics.

Numerous international and local studies have explored how game-based learning affects students' interest in mathematics. For example, a study by Bhadawkar and Gupta [26] used a quasi-experimental design and t-test analysis to show that elementary students who experienced game-based learning were more interested in mathematics than those in a control group. Similarly, research by Yeh *et al.* [27], investigated this approach in Taiwan, finding that both low- and high-achieving elementary students in the experimental group showed greater interest in mathematics than their peers in the control group. In Bayelsa State, Nigeria, Frederick-Jonah and Igbojinwaekwu [28] found that a game-enhanced instructional strategy significantly boosted primary students' interest in mathematics. A study in Abuja, Nigeria by Sumbabi and Bassey [29] revealed that secondary students who used mathematical games and simulations developed a stronger interest in geometry compared to those in a traditional learning environment. Lastly, in River State, Nigeria, research by Ezeugwu *et al.* [30] demonstrated that a game-based instructional approach increased junior secondary students' interest in algebra, with results indicating that gender did not affect the strategy's effectiveness.

According to the studies, game-based learning is an effective strategy for enhancing students' interest in mathematics. However, its impact on students' interest in mathematics in Enugu State, Nigeria, remains scarce. While previous studies used a quasi-experimental design, this study employs a true experimental design, specifically a repeated measures design, known for its high scientific validity. Moreover, unlike the reviewed studies, this study considers the influence of moderator variables such as gender, age, and location on students' interest. Thus, the present study aims to evaluate the effectiveness of game-based learning on students' interest in trigonometry in Enugu State, Nigeria. To guide this investigation, the study focuses on the following research questions:

i) What are the mean interest scores of students in trigonometry when exposed to the game-based learning approach?
ii) What are the moderating influences of gender, age, and location on students' interest in trigonometry using the game-based learning approach?

Based on these research questions, the study formulates two hypotheses: the first hypothesis (Ho1) states that the game-based learning approach does not significantly impact students' interest in trigonometry. The second hypothesis (Ho2) posits that gender, age, and location do not significantly influence students' interest in trigonometry when using the game-based learning approach.

2. METHOD

2.1. Design

This study employed a mixed-between and within measures analysis of variance (ANOVA) design. The researchers specifically used this design to determine whether the game-based learning approach impacted students' interest in trigonometry both within the groups (comparing pre- and post-test results) and between the experimental and control groups. This approach allows for a comprehensive analysis of the intervention's effectiveness by examining the changes over time and differences between the two groups.

2.2. Participants

A total of 56 senior secondary school two (SS 2) students (30 males and 26 females) between the ages of 14 and 17 years were enlisted to take part in the study. The sample size for this research was determined using the GPower 3.1 software, a tool that helps researchers calculate the necessary sample size to ensure their study has enough statistical power. For this study, we set the following parameters in GPower: an effect size of .25, a significance level of .05, a power level of .80, and used the F tests for ANOVA with repeated measures and between factors. Based on these parameters, GPower suggested a sample size of 56 participants, which is appropriate for detecting a medium effect size with adequate power. The use of G*Power for sample size calculation in experimental studies is well-documented and widely accepted in the research community [31], [32]. Some current studies [33]–[36] had applied GPower in determining sample size in recent times. Two public secondary schools (one in an urban and rural area) were selected randomly from the 16 public secondary schools in Enugu State's Udenu Local Government Area (LGA) with SS 2 students' population of 3,831 [37]. Participants in this current study were recruited from the schools chosen based on their trigonometry performance in mathematics assessment conducted by their regular math teachers before the investigation. Students with grades ≤50 were enlisted to participate in the study. Using Saghaei's random allocation software [38], we created a computer-generated random list to assign students to groups. This process resulted in 27 students being placed in the experimental group and 29 in the control group. Those in the control group were given the chance to experience the game-based learning intervention later. The average age of students in the experimental group (1.48±.51) was not significantly different from that of the control group (1.72±.46; t(54)=1.883, p=.065). Further details about the participants can be found in Table 1.

Table 1. Participants' demographic information (within-group analysis)

Characteristic dimension		Experimental group, n (%)	Control group, n (%)	χ^2	Significance
Gender	Male	14 (45.2)	17 (54.8)	.058	.809
	Female	14 (48.3)	15 (51.7)		
Age	14-15 years	14 (63.6)	8 (36.4)		
		1.48±.51	1.72±.46	*1.883(df=54)	.065
	16-17 years	13 (38.2)	21 (61.8)		
School location	Urban	15 (46.9)	17 (53.1)	.001	.972
	Rural	13 (46.4)	15 (53.6)		

Note: n represents the number of participants; χ^2=Chi-square; *t-test value

2.3. Measure

The trigonometry interest inventory (TII), which the researchers adapted from Snow [39] math's interest inventory, was used to gather data. The TII consists of 20 items and uses a 4-point Likert-type scale with response options: strongly agree (4), agree (3), disagree (2), and strongly disagree (1). Three research professionals validated the TII: one expert in measurement and evaluation and two experts in mathematics education. These experts reviewed the TII items for their phrasing, relevance to the research objectives, quality, and language. Based on their feedback, modifications were made to the TII. To assess the TII's internal consistency reliability, trial testing was conducted by distributing copies to a similar group of SS 2 students in a different area. This was done to determine how reliable the items were. The data gathered from the administration of the pilot testing was examined using Cronbach's alpha method, which produced an internal consistency reliability index of .85.

2.4. Procedure

The Post Primary Management Board, Udenu Zonal office, Enugu State, granted approval for the study on October 13, 2022, under reference number REC/PPSMB/22/00354. The researchers visited the schools involved in the study to formally obtain permission from the school heads before starting the investigation. The study was approved by the principals of the schools chosen. 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 research assistants for the study were the normal math's instructors at the chosen schools. One week of training on applying and teaching trigonometry concepts (trigonometric functions and their values in degree [sin, cos, tan, cot, cosec, and sec]) using the game-based approach was delivered by the researchers. Mathematics teachers in both the experimental and control groups were provided with lesson plans and notes as resources. The lesson plan for the experimental group was designed to incorporate game-based learning and included activities featuring the "hand trick" game and the board game "trig-conquest," created by Dueñas *et al.* [40]. The control group's lesson plan and note was developed using the conventional approach. Prior to beginning the actual treatment, the SS 2 learners took a pre-TII (Time 1).

The entire course of treatment took four weeks to complete. The administration of the post-TII test took place during the fifth week (Time 2). Before being used in the post-TII, the pre-TII items were rearranged to give the items a fresh look without changing their contents. The post-test results were noted and used to present information on students' performance of the trigonometric concept by gender and treatment group. Four weeks later, the post-TII items were also rearranged in preparation for the follow-up test (Time 3). Data on students' interests, categorized by gender and treatment group, was collected based on the follow-up findings.

2.5. Data analysis

The data was analyzed using version 28 of the statistical package for the social sciences (SPSS) software. A 2x3 mixed design was employed for the analysis, with group (experimental vs. control) as the between-groups factor and time (pre-TII, post-TII, and follow-up-TII) as the within-groups factor. In particular, the study questions were answered using the mean and standard deviation, and the hypothesis was tested using the F-test of repeated measures ANOVA. Mauchly's test of sphericity was not significant for the repeated measurement assumption in the ANOVA; Mauchly W=.873, p=.072. A repeated-measures ANOVA is predicated on the sphericity assumption. According to standard guidelines, an effect size greater than .01 is considered small, greater than .06 is medium, and greater than .14 is large [41].

3. RESULTS

Table 2 shows that students who participated in the game-based learning approach had a pre-test mean score of 55.07 (*SD*=8.19), a post-test mean score of 62.15 (*SD*=6.56), and a follow-up mean score of 70.89 (*SD*=4.93). In contrast, students who were taught using the conventional approach had a pre-test mean score of 55.34 (*SD*=5.43), a post-test mean score of 58.62 (*SD*=4.95), and a follow-up mean score of 57.24 (*SD*=6.49). The analysis of secondary school students' interest in trigonometry, corrected using the Greenhouse-Geisser method, revealed significant effects. There was a notable impact of the group (G) [$F(1,54)=27.429$, $p<.001$, $\eta^2_p=.337$], time (T) [$F(1.774, 95.80)=78.539$, $p<.001$, $\eta^2_p=.593$], and the interaction between time and group (G x T) [$F(1.774, 95.80)=42.086$, $p<.001$, $\eta^2_p=.438$], as presented in Figure 1. The univariate analysis of interest scores showed that the effect of the game-based learning approach on students' trigonometry interest in the experimental group was consistently strong [$F(1, 53)=47.658$, $p<.001$, $\eta^2_p=.485$, $\Delta R^2=.466$]. Therefore, the hypothesis is rejected.

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

Variables	Game-based		Control group		ANOVA				
(TII)	*M*	*SD*	*M*	*SD*	Effect	*F*-ratio	*Df*	η_p^2	95%CI
Time 1	55.07	8.19	55.34	5.43	G	27.429*	1, 54	337	[53.36, 57.06]
Time 2	67.15	6.56	58.62	4.95	T	78.539*	1.774, 95.80	.593	[61.34, 64.43]
Time 3	70.89	4.93	57.24	6.49	G x T	42.086*	1.774, 95.80	.438	[62.51, 65.62]

Note: M=mean; SD=standard deviation; CI=confidence interval; η_p^2=effect size; *p<.001

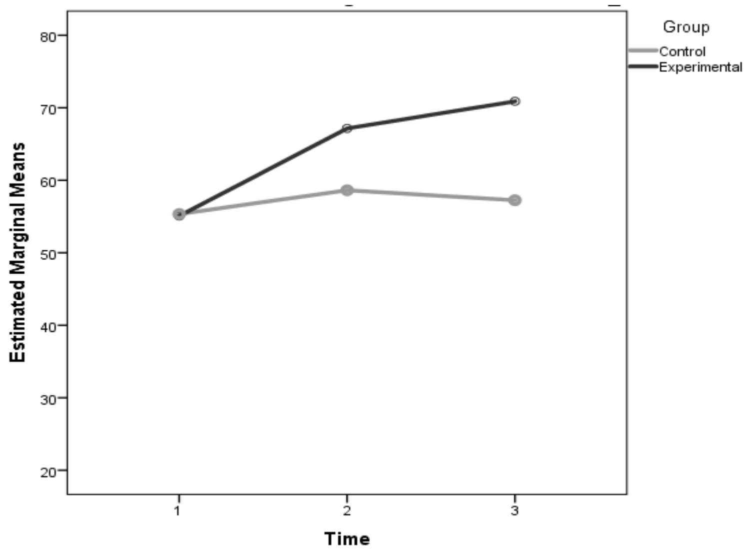

Figure 1. Time × group interaction effect

The result of the analysis in Table 3 revealed that the gender of participants exposed to the game-based learning approach indicates that male students had a mean interest score of 65.86 (*SD*=6.20) compared to their female counterparts, who had a mean interest score of 68.54 (*SD*=6.90). On the other hand, the table also revealed the age of participants exposed to the game-based learning approach indicates that students between the ages of 14-15 years had a mean interest score of 67.50 (*SD*=6.05) compared to their counterparts who are between the ages of 16-17 years that had a mean interest score of 66.77 (*SD*=7.31). Lastly, the table also revealed that the location of participants exposed to the game-based learning approach indicates that urban students had a mean interest score of 68.00 (*SD*=7.01) compared to their counterparts in rural, who had a mean interest score of 66.23 (*SD*=6.19). Table 4 reveals that the moderators (gender, age, and location) had no significant influences on the effect of game-based learning in fostering students' interest in trigonometry [$F(1, 40)=.135$, $p>.001$; $F(1, 40)=.145$, $p>.001$; $F(1, 40)=2.300$, $p>.001$]. Therefore, the hypothesis is not rejected.

Table 3. Analysis of the influence of moderator variables

Group	Moderator variables		N	Mean	Std. Dev.
Game-based learning (experimental)	Gender	Male	14	65.86	6.20
		Female	13	68.54	6.90
	Age	14-15 years	14	67.50	6.05
		16-17 years	13	66.77	7.31
	Location	Urban	14	68.00	7.01
		Rural	13	66.23	6.19

Table 4. ANOVA of the significant influence of the moderator variables

Source	Type III Sum of squares	df	Mean square	F	Sig.	Partial eta squared
Corrected model	1835.948[a]	15	122.397	4.970	.000	.651
Intercept	592.027	1	592.027	24.041	.000	.375
Pre TII	386.206	1	386.206	15.683	.000	.282
Group	518.747	1	518.747	21.065	.000	.345
Gender	3.321	1	3.321	.135	.715	.003
Age	3.566	1	3.566	.145	.706	.004
Location	56.630	1	56.630	2.300	.137	.054
Error	985.034	40	24.626			
Total	223199.000	56				
Corrected total	2820.982	55				

a. R Squared =.651 (Adjusted R Squared =.520)

4. DISCUSSION

The goal of this study was to evaluate how effectively the game-based learning approach enhances students' interest in trigonometry. The research revealed that students who learned trigonometry using the game-based learning strategy developed and increased their interest more effectively than those taught using conventional methods. The first hypothesis was tested, and the results showed that students in the experimental group exhibited higher interest in the mathematical concept than their counterparts in the control group. This demonstrates that the game-based learning strategy effectively increased students' interest in trigonometry. One reason for the success of game-based learning could be its ability to engage students actively in the learning process. Games often include elements such as immediate feedback, rewards, and a sense of accomplishment, which can motivate students and maintain their interest. Additionally, the interactive nature of games encourages student participation and collaboration, making learning more dynamic and enjoyable. These elements likely contributed to the heightened interest observed in the experimental group. This finding is consistent with previous studies [26]–[30], which reported that game-based learning is an effective strategy for increasing students' interest in mathematical concepts.

Moreover, the results indicated that gender, age, and location did not significantly affect the effectiveness of the game-based learning approach in fostering students' interest in trigonometry. This suggests that the increase in interest was uniformly distributed across different demographics. The lack of significant gender differences could be attributed to the positive influence of the game activities on trigonometry instruction, leading to increased interest among both male and female students. The active involvement and participation in game-based activities likely contributed to this outcome, corroborating the findings of Ezeugwu *et al.* [30], who reported no differences in interest between male and female students when using game-based instructional strategies.

The effectiveness of game-based learning can be further understood by examining the specific mechanisms at play. Cognitive engagement is heightened through problem-solving tasks and challenges within games, requiring students to apply their knowledge actively [18]. Emotional involvement is fostered through the immersive and enjoyable nature of games, which can reduce anxiety and make learning a more positive experience [42]. Social interaction within games promotes collaboration and communication among students, enhancing their collective learning experience [43]. These combined elements create a rich, multifaceted learning environment that traditional methods may lack. Additionally, games often provide a safe space for trial and error, allowing students to experiment without the fear of failure, further solidifying their understanding and interest in the subject matter.

4.1. Comparison with previous studies

Our study builds upon the findings of several researchers who have investigated the effectiveness of game-based learning strategies in enhancing students' interest in mathematics. Bhadawkar and Gupta [26] found that elementary school students in India demonstrated increased interest in mathematics when exposed to game-based learning, similar to our findings among secondary school students in Enugu State, Nigeria. Similarly, research by Yeh *et al.* [27], observed improved mathematics interest among elementary students in Taiwan using game-based learning environments, supporting our results with secondary school students in Enugu State, Nigeria. Research by Frederick-Jonah and Igbojinwaekwu [28] reported significant improvements in primary students' mathematics interest in Bayelsa State, Nigeria, through game-enhanced instructional strategies, mirroring our findings in a secondary school context. In Abuja Nigeria, research by Sumbabi and Bassey [29], discovered that mathematical games and simulations significantly boosted geometry interest among secondary school students, aligning with our observations on trigonometry interest in Enugu State. Research by Ezeugwu *et al.* [30] highlighted the effectiveness of game-based instructional approaches in enhancing algebra interest among junior secondary school students in River State, Nigeria, consistent with our findings on trigonometry interest.

4.2. Practical/empirical contribution

Our study provides empirical evidence that game-based learning can effectively enhance students' interest in mathematics, specifically trigonometry, across diverse educational contexts in Nigeria. This supports practical implications for educators aiming to foster engagement and motivation in mathematics through interactive and immersive learning experiences. The findings underscore the practical value of integrating game-based elements into mathematics education, aligning with the observed benefits in various demographic groups and educational settings.

4.3. Theoretical contribution

Our research contributes to the theoretical understanding of game-based learning's impact on student interest in mathematics by validating its effectiveness across different educational environments and demographic factors in Nigeria. This extends the theoretical framework by demonstrating consistent outcomes in enhancing motivation and engagement through interactive learning methods. The study supports social learning theory's principles of attention, retention, reproduction, and motivation by illustrating how game-based strategies facilitate active learning and knowledge application in mathematics.

4.4. Methodological contribution

Methodologically, our study employs a robust mixed-between and within measures ANOVA design, allowing for a comprehensive assessment of the differential impact of game-based learning on student interest over time and across groups. This methodological approach contributes to the literature by offering insights into effective educational interventions that can be adapted to diverse educational contexts and student populations. The border implications of these findings extend beyond immediate interest in trigonometry. Integrating game-based learning into various educational contexts could enhance student engagement across subjects. For instance, similar strategies could be applied to other challenging subjects, potentially improving overall academic performance, and fostering a more positive attitude towards learning. This approach is in line with modern educational practices that focus on student-centered learning and the cultivation of 21st-century skills like critical thinking, creativity, and collaboration. Additionally, using game-based learning strategies can accommodate various learning styles and needs, thereby making education more inclusive and accessible to all students.

5. CONCLUSION

The game-based learning strategy has demonstrated effectiveness in fostering interest in mathematics across various contexts, including trigonometry among senior secondary school students in Enugu State, Nigeria. Our findings align with similar positive outcomes observed in diverse settings, such as elementary and secondary schools in Nigeria, India, and Taiwan. Importantly, this study revealed that gender, age, and location do not significantly influence the effectiveness of game-based learning in enhancing students' interest in mathematics. However, the study has limitations, including its focus on a specific sample of SS 2 students in Enugu State, which may limit the generalizability of the results to other regions and educational contexts. Future research should include a broader range of participants from different year levels and locations, as well as performance metrics to assess the impact on academic achievement. Additionally, investigating the long-term effects of game-based learning on sustained interest and performance in mathematics, students' attitudes towards mathematics in higher education, and their career choices would provide valuable insights. Examining the cultural relevance and adaptability of game-based learning in different educational systems globally could enhance its applicability and effectiveness.

The study's findings have significant implications for educators and policymakers. Integrating game-based learning into the curriculum could enhance student engagement and interest in mathematics, potentially improving overall academic performance. To implement these findings effectively, mathematics teachers could receive training on incorporating game-based learning approaches into their lessons, particularly when teaching trigonometric functions. Educational policymakers could consider integrating game-based learning strategies into the national mathematics curriculum to create a more engaging and interactive learning environment. Additionally, schools could allocate resources to develop and implement game-based learning tools and activities in their mathematics programs, including investing in educational software, teacher training programs, and creating spaces conducive to interactive learning. In summary, we recommend that mathematics teachers incorporate the game-based learning approach in their lessons, and that the government and relevant educational agencies host seminars and workshops to support this implementation. Mathematics teachers should select and integrate appropriate game activities into their lesson plans to enhance students' interest in mathematics, ultimately improving their performance in the subject.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

INFORMED CONSENT

Informed consent was obtained from all subjects involved in the study.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author [FOE], upon reasonable request.

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