Evaluating the Effectiveness of Electronic Games-Based Learning in Enhancing Children's Multiplication Skills and Cognitive Achievement

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***Abstract*—This study aimed to evaluate the effectiveness of electronic games-based learning in developing children's multiplication skills and cognitive achievement. It addresses the growing phenomenon of declining academic engagement and inconsistent proficiency in foundational math skills among young learners, which conventional teaching methods often fail to resolve through leveraging the immersive and interactive nature of digital games as an educational medium deeply rooted in children's daily lives. The study explored whether technology-driven, game-based environments could bridge pedagogical gaps, sustain motivation, and deepen conceptual understanding of multiplication. The study involved a sample of 90 students, equally divided into an experimental group (taught using electronic games) and a control group (taught using conventional methods). A structured teaching program based on electronic games-based learning principles was developed, with research tools that have been validated for reliability and validity through rigorous pilot testing. The results indicated that the experimental group demonstrated improved multiplication skills, highlighting the effective impact of electronic games on learning performance in mathematics classes. Results also demonstrated the ability of these games to simplify abstract mathematical concepts and provide an engaging, enjoyable learning environment that enhances understanding of arithmetic operations. Considering these results, the study recommends integrating electronic games-based learning into mathematics curricula as a supplemental educational tool, given its role in boosting student engagement, maintaining interest, and nurturing cognitive abilities. It further advocates training programs to equip teachers with skills to effectively utilize digital games in instruction, alongside developing culturally relevant educational games aligned with local curricula to maximize their pedagogical value.**

***Keywords*—electronic games, multiplication skills, mathematics education, teaching methods, achievement test**

I. Introduction

Early childhood education requires students to learn mathematics, which of course includes basic addition and subtraction [1]. Broadly, it also includes counting concepts among children as well as more advanced form such as multiplication, division, or even algebra [2]. In particular, it is believed that operations like addition and subtraction improve the children's cognitive abilities on the finest matters including problem solving and decision-making and confidently overcome both academic and realistic problems after careful nurturing, so, mastery to these operations is considered the best way to boost one's potential to achieve [3]. Using the exercises provided for children can help build critical thinking and other important skills, since children are not only limited to addition and subtraction, but also these operations aid children in the everyday problems they face throughout their life [4, 5]. Math exercises also allow students to hone their logical reasoning skills which are essential to step into the real world and are necessary if problem solving and analytical thinking is to be used [2]. Children possess a variety of skills, which can be nurtured through ideal teaching methods and flexible curriculums, enabling educators to identify the best ways to develop students into great thinkers and problem solvers [1, 2].

Given the considerable progress in technology today, it is more important than ever to incorporate technology in teaching and learning processes. Such progress does not only involve the creation of sophisticated educational instruments, but also the improvement of pedagogical methods. One of the most notable advancements in teaching mathematics has been the introduction of electronic games, as these games motivate children to learn by combining education and fun as they learn [4–7]. Al-Barakat *et al*. [6] also assert that electronic games help enhance interactivity with the material taught, especially where the content entails a stepwise assimilation, as in mathematics. Furthermore, educationalists [1, 3, 5, 6, 8] have shown that when these electronic games are used to improve mathematical skills, there is a significant improvement in academic achievement of more than 30% compared to other methods.

A unique feature of electronic games is their capability to provide split exposure of education, both visually and audibly, cattered to different types of learners [9, 10]. Since children may not respond strongly to conventional forms of teaching, electronic games have the ability to get their attention by showing them strong imagery and sounds, and thus making learning enjoyable [10, 11]. Khasawneh *et al*. [11] observed that digital games which combine sight and sound capture all the senses of a child, thus making learning more active and enabling different types of learners. For instance, visual learners can appreciate colorful posters and those who are more inclined to listening can receive comprehensive verbal directions, making the learning environment more active.

Moreover, electronic games enhance learning by making it easier for children to learn while proceeding with the game, as the difficulty levels are structured in accordance with their skills [12–15]. This ensures that children are challenged but

not pushed to a point where they feel frustrated, which helps them to continue learning without becoming disheartened [16–18]. Parents continue to be motivated by these advancements, as obstacles overcome by their children urges them to aid their children in further skill advancement. Many researchers [19–27] have reported that games focusing on critical thinking and problem-solving skills are better in terms of learning effectiveness when compared to conventional instructional approaches. The same applies for complex operations of mathematics such as multiplication and division [28–30].

Another advantage of electronic games is enhancing children's attention and focus. There are numerous educational games that involve children in solving challenges that test their reasoning skills and demand high concentration. Many researchers [1, 5, 9, 11, 31–34] argue that games that require logical problem-solving skills help children focus more on what they need to remember. For example, "Math Blaster" and "Prodigy Math" offer a fun-filled experience to learners where learners get to understand mathematical operations like addition, subtraction, multiplication, and division through playing fantastic games [12, 35–37].

Many previous studies [38–42] have analyzed the effectiveness of conventional and electronic learning games in subjects such as mathematics, reading, spelling, and even algebra. However, the vast majority of them did not concentrate on how these games helped teach basic math operations, especially multiplication. This study aims to fill that gap by studying the impact of electronic educational games on the multiplication skills of second-grade students, as multiplication is an essential skill that affects children's academic development in higher grades.

Researchers have noticed through working with first- through third-grade students that many students seem to have difficulty understanding multiplication, and that, consequently, adversely impacts the overall performance in mathematics, which has been recognized as essential for a child's development. Previous studies [43, 44] have pointed out that the objectives or targets that were supposed to be accomplished in primary mathematics teaching were not achieved, which resulted in gaps of understanding on the basics. There is a need to rethink and change the approach to teaching these students with the goal of promoting mastery of these concepts. This study is in line with a new approach towards self-learning facilitated by technology [45, 46], which is also in line with the initiatives set by the Saudi Arabia Ministry of Education for the enhancement of technology in the math curriculum and the overall shift towards digital content.

The purpose of this research is to employ games in multiplication for second grade students and figure out how to improve the learning process through technology at this level. The research is essential because it seeks to understand how electronic educational games can improve overall motivation and learning among students in a specific area, namely mathematics teaching. The enhanced features offered by electronic games including sound, graphics, and interaction may improve student motivation and overall learning as well.

Moreover, the research aims to fundamentally change the mindsets of those teachers and parents who are reluctant to use innovative methods, such as games, in their math instruction, improve educational outcomes, and enhance the way electronic tools and games are integrated into mathematics instruction, thereby achieving attitudes toward modernization of instruction. Furthermore, there is a contribution towards effective pedagogy that integrates technology into teaching and addresses current issues within education.

This study is also motivated by the search for suitable methods of teaching mathematics. More specifically, it aims to assess the impact of electronic game-based lessons on child students' multiplication skills and cognitive achievement. In pursuance of this, the study will answer the following research questions:

1) Are there statistically significant differences (at the $p \leq 0.05$ level) in acquiring multiplication skills between students who were taught using electronic games compared to those taught using conventional methods?
2) Are there statistically significant differences (at the $p \leq 0.05$ level) in cognitive achievement between students who were taught using electronic games compared to those taught using conventional methods?

II. Method and Procedures

A. Study Design

The study design was quantitative and quasi experimental. Participants were allocated into two groups, the experimental and control groups. The experimental group was subjected to game-based learning while the control group was instructed by conventional methods of teaching. The conventional method, in this instance, refers to standard practices of teaching that mainly involve transferring knowledge through direct teaching, including lessons from textbooks or lectures. This method usually involves drills and practice sessions, with little emphasis on reality or other technologically enhanced interactive aids. The main assessments comprised a pre-test that focused on the students' prior knowledge of the subject, as well as a post-test that determined whether the experimental group benefited from the learning program. Such measures were possible because the data collected from students' multiplication abilities was valid to make accurate comparisons between the two teaching techniques.

B. Study Population and Sample

The study population included students from the second grade of primary schools in the Al-Ahsa region of Saudi Arabia during the second semester of the 2023/2024 academic year. For this study, six primary schools were chosen as the headmasters and teachers were willing to cooperate with the researchers, so the environment was conducive for the study.

The study sample consisted of ninety students who were grouped into two main groups: In the experimental group, there were 45 students who were placed in three different schools and practiced their multiplication skills through games. In the control group, there were also 45 students who were placed in three different schools and received direct instruction with the use of textbooks and drills.

Students were divided into two groups based on their level of academic attainment; Each group was made up of students

that had a mix of high, moderate and low academic performance. Furthermore, as a measure to control the elements that might affect the outcome of the study, students from both the groups were made to have similar socioeconomic status, this helped ensure that the results of the study would genuinely demonstrate the effect of game-based learning on multiplication skills. The approach taken for this study provided an attempt at making a fair comparison in the outcome of the two groups so that reliable conclusions could be drawn.

C. Data Collection

Collecting the data for the study required designing a Learning Program Based on Electronic Games, along with formulating a multiplication test and a cognitive achievement test. Each instrument is described below:

1) Learning program based on electronic games: An overview

The learning program based on electronic games was developed to improve students' multiplication skills, using modern pedagogical approaches such as constructivism, group work, and technology utilization. The program aimed to relate mathematical ideas to the real world and encourage the students to participate actively in lessons. The primary means of the program were electronic games, which included the "Repeated Addition Game", "Tower Building Game", "Car Racing Game", and "Space World Game," to allow the students to use mathematics actively and practically as well as enhance their understanding of the topics.

Modern teaching methods were adopted, such as learning by playing games and group work, to develop students' problem-solving capabilities. Each game was set to a specific time frame, adjusted for difficulty, and feedback was provided after each answer was given. The strategies aimed at improving the multiplication skills of the learners along with critical and creative thinking.

Moreover, students' progress was measured through a variety of assessment methods, such as using interactive assessments within the games, which gave students feedback concerning their performance almost instantly, thus fostering their engagement with the activities. The teaching plans were carefully crafted and vetted by education specialists to ensure that they meet the specifications of the program.

Besides, the teachers were prepared to implement the program after attending training sessions designed to introduce them to the practical application of the program's components in real classrooms. This training enabled teachers to determine the usefulness of the methods implemented in lessons and how to modify them to meet the students' needs. With these measures, the program was ready to be effectively implemented in real classrooms.

2) Test of multiplication skills

The multiplication skills assessment was created to evaluate children's ability to use multiplication skills in different areas of learning and how efficient they can be in performing tasks and activities related to mathematics lessons. This assessment had several components: the first component is multiplying by 1, which is one of the fundamental mathematical operations of multiplication, since it shows that any number multiplied by one retains the value. This part of the test aimed to measure students' understanding of this rule and their ability to apply it in simple multiplication exercises. The next part, multiplying by 2 was applying the concept of counting in repetitions as in $2\times3 = 3+3$, this part determined how well the learners know the concept and whether they can apply it to the given problems or not. The last component was multiplying by 3 which requires counting items or objects thrice, such as in $3\times4=4+4+4$, this part of the examination tested the students' data organization and calculations skills.

To evaluate student performance, two primary tests were developed: the Multiplication Skills Test and the Cognitive Achievement Test. The validity and reliability of both tests, as well as their appropriateness for second grade students, were thoroughly reviewed for the study. Test items were reviewed by a panel of Saudi university mathematics educators and curricular specialists to ensure clarity and accuracy in relation to the students' cognitive level. Some modifications were made for balance across knowledge, understanding, and application domains. The Multiplication Skills Test was itemized to 15 questions, and the Cognitive Achievement Test was itemized to 15 questions.

A pilot test on a sample of 23 second grade students was performed to assess and measure the clarity of the test items as well as the time required to complete them. Difficulty and discrimination indices were calculated for both tests, which were found to be adequate given the ranges of 0.51 to 0.79 for the difficulty indices. Discrimination indices for measuring high and low achievers ranged from 0.43 to 0.77, with an alpha coefficient of 0.89, demonstrating high test reliability; test-retest reliability was 0.96.

To confirm the construct validity, Confirmatory Factor Analysis (CFA) was conducted on AMOS version 25.0. (CFA) is a part of SEM that is performed to determine the associations between the latent variables and to discover the data patterns. CFA is fundamentally important for validation because it checks the main dimensions and factor loadings of the measurement instrument and its latent structure. The final version of both instruments was given to the study sample to check for factorial construct validity, the CFA presented in Fig. 1 was used to check the correspondence of the scale items to their dimensions.

D. Data Analysis

The data collection commenced after preparing and validating the study tools with the application of a pre-test to both the experimental and control groups. This was performed prior to the introduction of the electronic game-based learning method. The purpose of the pre-test was to ensure that both groups had the same starting level of performance which was necessary for obtaining valid results for the experiment.

A game-based learning approach was utilized for the experimental group where students learned through interactive electronic games, while control group students were taught through conventional methods without the incorporation of electronic games. This made it possible to evaluate the impact of game-based learning as opposed to conventional teaching on student performance.

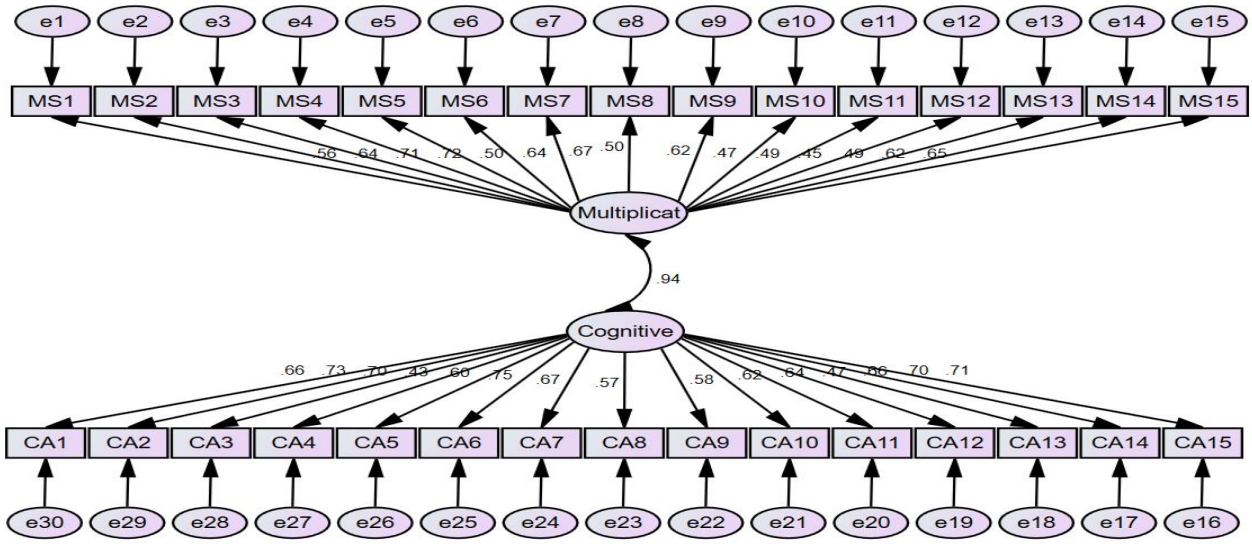

Fig. 1. The findings from the confirmatory factor analysis to determine the association between the items in both instruments, as well as the extent of their loading.

SPSS version 26 was used to analyze the data obtained from the pre-test. The analysis involved means and standard deviation, and a T-test to assess the differences between the groups' performance, as illustrated in Table 1.

Table 1. Pre-test results of multiplication skills and the cognitive test

Tests	Group	No.	Mean	St. dev.	T-value	df.	Sig.
Multiplication Skills	**Experimental**	45	2.78	1.376	0.474	88	0.695
	Control	45	2.80	1.370			
cognitive test	**Experimental**	45	2.50	1.244	0.568	88	0.732
	Control	45	2.51	2.221			

A relative parity between the two groups' scores can be inferred from Table 1, since there was no significant difference in the scores of the two groups in the multiplication skills and cognitive test; (T-value = 0.474, Sig. = 0.695 for multiplication; T-value = 0.568, Sig. = 0.732 for cognitive test), this result indicates that both groups began with quite equal performance.

The teachers of the experimental group were then enrolled in a 30-hour training course over three weeks to be taught how to use the electronic games learning strategy in the classroom. After the training course, the experimental group was taught using this teaching method, while the control group learned using conventional methods. Later, both groups underwent the final test to measure the effect of the two different methods of teaching on the students' multiplication achievement. The scores of the post-test were processed by computing the means and the standard deviations of the two groups, and then the analysis of the electronic game-based learning method was conducted.

III. Results

A. Analysis of Multiplication Skills Results

The first question of the research was to measure the effectiveness of a learning program that incorporated electronic games in teaching multiplication skills to children. Therefore, the arithmetic means, and standard deviations were calculated for the performance of children in the multiplication skills test for both experimental and control groups. A t-test was performed to determine if the experimental group achieved multiplication skills significantly better than the control group as a result of the electronic game-based learning approach, Table 2 illustrates the results.

Table 2. Participants' performance on the post-test of multiplication skills

Group	No.	Mean	St. dev.	t-value	df	Sig.
Experimental	45	14.573	0.458	116.84	88	0.01
Control	45	8.75.	4.3.60			

The results in Table 2 highlight a significant difference between the performance of both experimental and control groups, as the experimental group had a mean score of 14.573 compared to the control group that had a mean score of 8.75. This illustrates that the application of game-based learning strategies produced positive impact on the multiplication skills of the students in the experimental group.

In the experimental group, the variance was at a standard deviation of 0.458, meaning that participants' scores were around the average. This level of variance suggests that all participants were similarly affected by the intervention. On the other hand, the control group had a variance value of 4.360, meaning that average performance was lower. This difference demonstrates the more controlled and focused approach of game-based learning compared to more relaxed conventional methods.

The results of the t-test indicated a t-statistic of 11.684 with 88 degrees of freedom and a *p*-value less than 0.05, confirming the existence of a statistically significant difference and making the outcomes of the intervention dependable.

The above findings show a positively strong correlation between the level of game-based learning a teacher implements and the achievement in the multiplication skills among second-grade students in Al-Ahsa, Saudi Arabia, demonstrating that there are fundamental components of engagement or interactivity embedded within the structure of

game-based learning that enhance learner performance.

B. Analysis of Math Achievement Results

The second research question sought to analyze the extent to which the electronic game program assisted the children in achieving the desired level of cognitive development. Here, the arithmetic means, and standard deviations of the performance were calculated for each of the achievement test groups for both the experimental and control groups. The results are presented in Table 3 which highlights the metrics of both groups, thus shedding light onto the impact and outcome of learning through electronic games as opposed to more conventional methods of teaching.

Table 3. Results of participants' performance on the post-cognitive achievement test

Group	No.	Mean	St. dev.	t-value	df.	Sig.
Experimental	45	14.65	1.413	10.721	88	0.00
Control	45	9.82	2.745			

3 reveals a significant difference in achievement between the experimental and control group, providing insight into the power of game-based learning in helping to raise student achievement levels. From the data given in the table, the following are the findings that the study illustrated.

The t-value of 10.721 and a p-value of (0.00) indicate that the statistics are very significant. It has already been shown that the use of electronic game-based learning does positively affect the academic achievement of students as opposed to the conventional methods, the value of *p* which is less than 0.05 supports the null hypothesis and also makes the results of the research credible and precise. The average performance score of the experimental group was 14.65, while the average performance score of the control group was 9.82.

From the results obtained, it can be argued that electronic game-based learning is a more dependable and better method for improving the students' academic achievement than the other methods of teaching. Digital games have been found to not only capture the attention of students but enable teachers to customize the learning experience for maximized scholar performance.

IV. Discussion of the Results

The research findings indicated that learning via digital games was helpful in enhancing the experimental group the multiplication facts. Hence, the game-based approach positively impacts the students' overall performance in mathematics, particularly in multiplication. The result of the study supports the hypothesis formulated at the beginning which states that the use of game-based methods does enhance multiplication skills among students.

The success of game-based methods can be attributed to the fact that they are in line with the interests of the children. In other words, teaching with game-based approach aids students in material engagement and active participation through the learning process, as gamified structures which include features, rewards, and feedback loops help engage the students and motivate them to practice and hone their skills. This approach to learning not only increases enjoyment, but also motivation of the students to grapple with more difficult concepts like multiplication as they are motivated by the game-like features and the feedback given.

Similarly, video games can be built in a manner that incorporates a wide range of challenges based on the individual's achievement so that learners are able to master at their own pace which motivates them to learn more. This is useful in trying to make the student work within the logical level of development, while guaranteeing mastery of the basic mathematical concepts. This approach also enhances the use of individualized instruction, as it seeks to structure the learner's experience where learners are able to self-regulate learning based on their knowledge and skills. Accordingly, the learning aspect of game-based education is quite essential in developing the students' mathematical skills and capabilities.

This is beneficial because it helps students adopt the skills in more real-life situations. Moreover, students get a chance to use the abstraction of the mathematical knowledge they learn in class through the applied integration of game-based activities in the curriculum. This action makes the material more relevant and easier to comprehend, consequently, students will gain a better understanding of mathematical concepts.

From the researchers' perspectives, these results emphasize the importance of adopting game-based learning at the primary level, particularly in mathematics. This paper demonstrates that using games as a means of teaching students the basics of mathematics can not only capture students' attention but can also help them appreciate and understand concepts in a variety of exciting ways. There are many benefits of game-based learning as it is taught to different levels and needs, which when engaged, enhance the development of skills in a stimulating and enjoyable environment.

The study findings are in line with prior studies [11, 15, 17, 19, 23, 25], which revealed that students who learned mathematics with electronic games performed better than students who learned using conventional methods. Moreover, the findings are consistent with previous studies [11, 18, 23, 34, 47–49] that attempted to address student engagement by integrating games into the instructional processes and learners' mathematics skills. From the literature, it has been found that learners who use educational games as learning tools improve in certain subjects while achieving higher ranked skills such as critical thinking, problem solving skills, and even retention that can be useful in other dimensions of learning and daily activities [1, 2, 3, 4, 50, 51].

It is evident that video games can aid in the development of core cognitive and metacognitive skills. From problem solving, to determining the course of action, and even making thoughtful decisions, games greatly enhance a player's strategic thinking, cognitive flexibility, and much more. Based on what was mentioned in previous studies [52–54], these skills are essential to an individual's academic performance as well as achieving self-development since they allow logical and creative problem solving. Furthermore, when students engage in educational activities through game-based learning, their attitude toward studying improves because these activities are thought to be engaging, enjoyable, and fruitful, instead of being overly frustrating and stressful.

In addition, the results of the second question revealed that participants in experimental settings progressed in cognitive

achievement more than those in control settings. Therefore, the differences in cognitive achievement between the two groups were clear and statistically significant. Consequently, these findings suggest that more students are able to achieve better cognitive skills when they are taught with games, since this method is far more effective than conventional teaching methods.

The control group did not actively participate in the learning process when compared to the experimental group, this is due to the fact that electronic games facilitate the creation of learning environments rich with activities targeted at improving the students' understanding of mathematical concepts. A number of different researchers have pointed out that these types of interactive methods foster involvement in the learning process more effectively.

The control group had significantly lower cognitive achievement as expected, this could stem from the absence of stimulating inquiry and challenge features that electronic games provide. Such disparities in cognitive achievement suggest that the motivation generated by the use of electronic aids may be important in improving students' overall academic performance.

These findings corroborate with other investigations, for example, the study conducted by Al-Barakat *et al.* [6] which revealed that educational games assist in developing skills of critical thinking and problem solving. Based on Kärki *et al*. [17], the use of games in instruction improves the process of learning. Therefore, from these studies, it can be concluded that game-based learning not only improves cognitive achievement but also facilitates positive attitudes towards learning and raises students' motivation towards learning.

V. Conclusion and Future Research

The research concluded that electronic game-based learning increases student engagement, understanding, and performance. This new model of teaching moves away from traditional approaches because children find it easier to interact with complex ideas, such as multiplication, using sophisticated forms of electronic games, as electronic games allow learners to progress at their own speeds, which, in turn, results in responsibility, interest, and enhancement of performance at school.

Therefore, the research proposes that the use of technology, especially educational games, should complement conventional teaching, since they serve enhancing lessons and making them more appealing, and create a more active learning situation. At the same time, these games help to build several important cognitive skills and other personal skills needed today, such as problem solving, perseverance, and teamwork.

Moreover, the research calls for an adoption of an electronic game-based approach in subjects like mathematics that are difficult to grasp for students in the traditional classroom. To achieve this effectively, it was proposed that teacher-training programs should be designed to assist teachers in integrating learning games into their teaching. Moreover, there should be cooperation between educators, policymakers, and game developers to develop culturally relevant and context-specific educational games.

Despite the positive aspects, there are still some limitations. The study was conducted at a single selected public-school in Saudi Arabia, hence, the results cannot be generalized to all schools. Therefore, future studies should expand the targeted population to include students from different schools and regions. Besides, using qualitative techniques like interviews or group discussions should help provide further insight into the impact of game-based activities on the learning atmosphere and the level of engagement of the students.

Finally, future trends of research should look into the impact of game-based learning on students achievement and even their self-growth over an extended period of time, since such longitudinal analysis can give valuable information on the impact of those games on the learning processes of students across time and determine which characteristics of game-based learning, interactivity, feedback, or story-telling, are useful in education. Looking at these characteristics functioning in cooperative and group work would also enhance understanding of their contribution and scope.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

A.A.A. and R.M.A -B. conceptualized the manuscript's focus, proposed the aims, prepared the draft manuscript, and wrote all the sections. O.M.A. and Y.Z.A. collected, analyzed, and interpreted the data. A.A.A. and R.M.A-B. were major contributors to writing the manuscript. All authors read and approved the final version of the manuscript.

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