Impact of Augmented Reality onthe Academic Performance of Senior Secondary Students in Mathematics in Ile-Ife, Osun State, Nigeria

Abstract

The objective of this study is to examine the impact of Augmented Reality on the learning outcomes of senior secondary school students in Ile-Ife, Nigeria. This study is also aimed at determiningthe level of students' performance in Mathematics when taught with the traditional chalk and talk method and Augmented Reality in senior secondary schools in Ile-Ife, Nigeria. It also investigated the challenges of Augmented Reality on the academic performance of senior secondary schools in Mathematics in Ile-Ife, Nigeria.This research adopted the descriptive survey research design. The population for the study comprised students in Senior Secondary School I, II and III in Ile-Ife, Osun State. Stratified sampling technique was used for the research. The stratification index was the method of teaching. The students were grouped into two. These included students who were taught with the traditional chalk and talk method and those who were taught with Augmented Reality devices. Twenty public and 20 private schools were purposively selected for the research giving a total of 40 schools. The sample consisted of students in their intact classes selected at random. A total of 1341 students comprised the sample size. Seven hundred and nine were taught with AR while 632 were taught with the traditional chalk and talk method. Two research instruments were used to collect data for the study. These instruments included Augmented Reality Participation Questionnaire (ARPQ) and Mathematics Performance Test (MPT). The data collected were analysed using appropriate descriptive and inferential statistics. The result showed that the level of performance of students who were taught with the Augmented Reality (AR) method was high. The study further revealed that the mean score of students taught with the in the AR method in Mathematics was 37.63 while the mean score of the students taught with traditional chalk and talk method was 25.41.The result also showed that the students who were taught with the Augmented Reality (AR) method performed better in Mathematics than those taught with the traditional chalk and talk method ($F = 22.46$, $p < 0.05$). Furthermore, the result showed that students' level of participation in thelearning of Mathematicalconceptswith ARsignificantly affects their performance in Mathematics in the study area (Adjusted $R^2 = 0.510$). The study concluded that secondary school students who are taught with Augmented Reality in senior secondary schools in Ile-Ife, Nigeria performedbetter than those taught with the traditional chalk and talk method.The study hereby recommends that educators, policymakers and other stakeholders in the Nigerian educational systems should explore the integration of AR technology in Mathematics classrooms.

Keywords: Augmented Reality, Ile-Ife, Nigeria, Mathematics, Senior Secondary Schools

1.1 Introduction

Mathematics, as a subject, is essential for the scientific, technological, social and economic advancement of all nations across the globe. This is because every individual requires a certain level of mathematical knowledge to survive and function effectively in his immediate environment as well as in a highly technological and complex society. Hence, the inclusion of Mathematics in the curricula of secondary schools or its equivalent in most countries of the world such as United Kingdom (UK), United States of America (USA), India and Nigeria. Mathematics is a compulsory subject in Senior Secondary School curricula in Nigeria and it is central to learning in arts, social sciences and sciences. The performance of senior secondary school students in the subject has not been impressive in external examinations especially those conducted by the West African Examination Council (WAEC) and the National Examinations Council (NECO) for more than two decades (Eze and Ikpe, 2023). The annual deterioration in the performance in Mathematics inexternal examinations have been attributed to lack of teachers' commitment to their vocation, inadequate man power, poor method of teaching, large class size, anxiety, abstract nature of some concepts in Mathematics, students' attitude to learning amongst others. Hence, a lot of students are denied admission into tertiary institutions to further their studies annually. Several efforts such as the introduction of incentives for improving the teaching and learning of Mathematics and the organisation of workshops and seminars have been put in place by the government at all levels to reduce the mass failure in Mathematics (Akanni, 2016). In spite of these, the performance of senior secondary school students in Mathematics remains abysmally poor. This is manifested especially when the termly results as well as the results of WAEC and NECO are released. Consequent upon this, this research seeks to examine the impact of Augmented Reality (AR) on the academic performance of Senior Secondary School students in Mathematics.

AR is an enhanced, interactive version of a real world environment which is achieved through computer generated elements such as audio, text, video and images via holographic or 3-Dimensional technology in a virtual environment (Uğur & Apaydın, 2014). Hence, AR can be viewed as an environment that is supported by both real and virtual objects in real time. The virtual object appears to coexist in the same space as objects in the real world in an AR environment (Azuma et al., 2001). Interaction with the virtual content in AR is achieved via computers, hand gestures, voice and haptic gloves. The aim of AR is to add information to a real environment which helps to improve the users' view of the real environment. From the foregoing, AR enhances a user's perception of his environment as well as the user's interaction with the environment. This is because the virtual objects in AR display information that the user cannot detect directly with the sense organs (Azuma, 1997). The five primary sense organs that are the senses of sight, smell, touch, hearing and taste structure the existence of reality in humans. Nonetheless, these organs can only perceive 5% of the universe (Carmigniani and Furht, 2011). AR can however be deployed to augment the sense organs as well as substitute missing senses by sensory substitution through the provision of cues such as audio cues for the deaf and visual cues for the blind.AR applications that allow real objects to be removed from the environment are tagged mediated or diminished reality. The goal of removing real objects from the real world is to cover the object with virtual information that matches the background in order to give the user the impression that the object is

not there. On the other hand, virtual objects added to the real environment presents information that the user cannot directly detect with the sense organs. AR can therefore be viewed as a computerized extension of people's reality in a system which is characterized by three key features: combined reality and virtuality, interactive in real time and presented in 3D (Dutta, 2020).

The application of AR cut across diverse domains which include healthcare, military, robotics and telerobotics, entertainment and infotainment as well as education. AR, although a nascent technology in education, has proven to be a valuable tool for education in developed countries such as United States of America and China to make learning fun, stimulating and more engaging. It allows students to easily learn concepts with the aid of both real and computer-generated images. This no doubt enhances students' motivation, engagement, involvement and comprehension of concepts in a class setting. It also enables students to visualize complex spatial relationshipsand abstract concepts as well as have experiences that are not possible in the real world (Chang et al., 2013). These benefits of AR in education have no doubt made AR one of the main emerging technologies deployed in recent times. Nonetheless, there is very limited research on the impact of AR on the academic performance of students in Nigeria. Hence, this research seeks to examine the impact of Augmented Reality on the learning outcomes of Senior Secondary School students in Nigeria. The research focuses on senior secondary schools students in Ile-Ife because poor performance in Mathematics in external examinations is quite pronounced at this level in Osun State.

1.2 Statement of Problem

There has been a public outcry over the persistent poor performance of senior secondary school students in Mathematics in both internal and external examinations in Nigeria. This poor performance is often attributed to fear and anxiety, abstract nature and complexity of some concepts in Mathematics as well as the continual use of the traditional chalk and talk method which is yet to pave way for technology driven teaching methods such as the use of Augmented Reality. This incidence of poor performance has triggered various reactions on how this issue of poor performance in Mathematics can be resolved. These reactions include the provision of remedial classes for students and professional development programmes to update the knowledge and mastery of secondary school teachers in Mathematics. Hitherto, this challenge is yet to be tackled. This present research however seeks to examine the impact of Augmented Reality on the academic performance of senior secondary school students in Ile-Ife, Nigeria.

1.2 Research Questions

This study answers the following questions:

i. What is the level of students' performance in Mathematics when taught with Augmented Reality in senior secondary schools in Ile-Ife, Nigeria?
ii. What isthe effect of Augmented Reality on the academic performance of senior secondary schools in Mathematics in Ile-Ife, Nigeria?

iii. What are the challenges of Augmented Reality on the academic performance of senior secondary schools in Mathematics in Ile-Ife, Nigeria?

1.3 Hypotheses

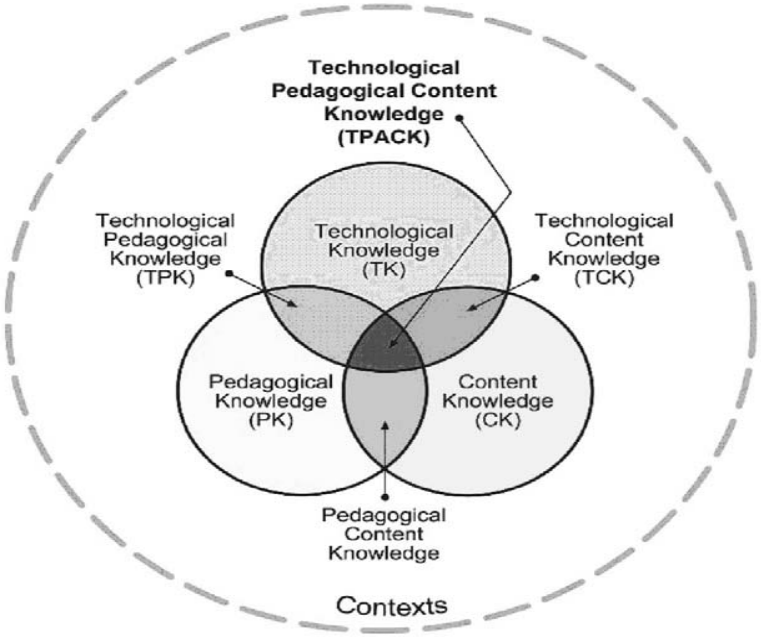
The following hypotheses are also tested:

i. Students who are taught with traditional chalk and talk method do not perform better in Mathematics than students taught with AR in the study area; and

ii. Students' level of participation in the learning of mathematical concepts with AR will not significantly affect their performance in Mathematics in the study area.

2.0 Theoretical Framework

This study is centered on two theories which include: Technological Pedagogical Content Knowledge (TPACK) and theory of didactical situations in Mathematics. Technological Pedagogical Content Knowledge (TPACK) is a model that identifies the nature of knowledge required by teachers for integrating technology into the teaching process while taking into cognizance the complex, multifaceted and situated nature of the teacher's knowledge (Koehler and Mishra, 2009). The TPACK framework is based on Shulman's construct of Pedagogical Content Knowledge (PCK) which is centered on technology knowledge as situated within content and pedagogicalknowledge (Schmidt et al., 2009). The TPACK framework specifies the relationship amongst the three basic forms of knowledge which include technology, pedagogy, and content. The TPACK model consists of seven elements which are specified in Figure 1 below.



The components

a) **Technology Knowledge (TK):** This refers to the knowledge about the technologies that will be employed in the classroom for teaching and learning. The technologies can range from low

technologies such as pencil and paper to digital technologies such as the Internet, digital video, interactive whiteboards and software programs. The knowledge about the technology and tools to be employed in the classroom will assist the teacher to apply it productively for teaching. It will also enable the teacher to know when the technology can assist or impede the learning goals during teaching and learning process. This component of TPACK will also assist the teacher to adapt to changes in technology (Koehler and Mishra, 2009).

b) **Content Knowledge (CK):**Content Knowledge is the knowledge about the actual subject matter that is to be learnt or taught in the classroom (Mishra & Koehler, 2006). This component of TPACK emphasizes that teachers must know the content they are going to teach and how the nature of the knowledge is different for various content areas. This knowledge includes knowledge of concepts, theories, ideas, organisational frameworks as well as knowledge of evidence and proof.

c) **Pedagogical Knowledge (PK):**This refers to the teacher's knowledge about the methods and processes that are deployed for teaching. Examples of PK include knowledge in classroom management, students' assessment, lesson plan development, general classroom management skills and student learning. PK also encompasses the overall educational purposes, values, and aims.

d) **Pedagogical Content Knowledge (PCK):**Pedagogical content knowledge refers to the content knowledge that deals with the teaching process (Shulman, 1986). This component of TPACK emphasizes that the teacher must be able to interpret the subject matter to be taught in the classroom and finds numerous ways to represent the contents while adapting the instructional materials to alternative conceptions and students' prior knowledge.

e) **Technological Content Knowledge (TCK):**Technological content knowledge refers to the knowledge of how the teacher uses technology to create new representations for specific contents. According to Koehler and Mishra (2009), teachers must understand the specific technologies that are best suited for addressing the subject-matter in their domains.

f) **Technological Pedagogical Knowledge (TPK):**Technological Pedagogical Knowledge refers to the knowledge of how technologies can be used in teaching. It also emphasizes that the teachers must understand that the use of technology may change the way teachers teach.

g) **Technological Pedagogical Content Knowledge (TPACK):**Technological pedagogical content knowledge refers to the knowledge that a teacher requires for integrating technology into the teaching of contents. This component indicates that the teacher must teach contents using appropriate pedagogical methods and technologies.

In linking this theory to this study, it should be understood that a student's cognitive growth and development can be enhanced when the teacher employs the use of technology. It can also be deduced from the theory that students who are taught with technological gadgets are more likely to excel academically while in school than those who are not taught with the use of technological devices.

The theory of didactical situations in Mathematics propounded by Broussea(1998) emphasises that knowledge is a property of a system constituted by a subject and a milieu in interaction (Mackrell, 2013). This theory is of the view that learning occurs through the interaction between the subject and the milieu which includes the technology used for the teaching of Mathematics or a part of the technology that is relevant to the concept of Mathematics taught. The theory emphasizes that the milieu is determined by the teacher in the learning environment who also creates all the elements that the students will work with as well as the objects that the students will manipulate in the technologically driven learning environment. The milieu allows the students to work autonomously and learn some specific mathematical contents by following the rules associated with the technology as well as reflecting on this action by considering the feedback of the milieu. The teacher is however expected to interact with the milieu before the class or during the class while considering the interaction between the students and the milieu and the consequences on the students' knowledge. The theory states that the teacher uses this information to modify the milieu in order to assist the students during the learning of Mathematical concepts. The students on the other hand consider the action on the milieu, reflect on it and then use it to produce new knowledge (Mackrell, 2013). In linking this theory to this research, it should be understood that technology plays a vital role in the teaching of Mathematical concepts at all levels of the educational system. This framework aids in understanding that technology facilitates autonomous learning in students which in turns allows them to learn at their own pace. Furthermore, the framework helps to understand that technology facilitates communication and interaction between the teacher and students. This interaction is positively associated with self-esteem, determination and optimism in the learning of Mathematical concepts.

3.0 The Structure of the Nigerian Educational System

Education is a basic human right that is enshrined in the constitution of the Federal Republic of Nigeria. The Nigeria educational system operates on a 9-3-4 system where each number represents the number of years spent at each level of education. These levels include the basic and post basic education, senior secondary education and the tertiary or higher education. The basic education consists of pre-primary, primary and junior secondary school programs. The basic education is mandatory for all children in Nigeria and pupils and students are expected to spend a period of nine years at the level of basic education. The post-basic education covers three years of senior secondary education in either an academic, vocational or technical institution.At the end of the 3-years program in an academic senior secondary school, students are required to write the WAEC and/or NECO examinations and the Joint Admission Matriculation Board examination. These examinations qualify students to proceed to tertiary institutions or higher education. Students are however required to have at least a credit pass in Mathematics and English Language.The tertiary is made up of a university and a non-university system which includes polytechnics, monotechnics and colleges of education. Students at this level of education usually spend between 4-7years in schoolsdepending on the course of study.The levels of education in Nigeria is maintained and controlled by the three tiers of government which include the federal, state and local governments. In addition, private individuals and religious organisations collaborate with the government at all the tiers to maintain the educational system in Nigeria. While the Federal government engages in policy formulation and quality control of education majorly at the tertiary level, the state and the local government maintain education at the basic and post basic levels of education in Nigeria. The use of technology at the three tiers of Nigeria educational system is still at its lowest ebb.Consequently, the benefits of technologyare yet to be fully realized in the Nigeria educational system.

4.0 Students' Performance in Mathematics in Senior Secondary Schools in Nigeria

It is apparent that Mathematics is a compulsory and a pre-requisite subject for students seeking admission into Nigerian tertiary institutions. Consequently, Mathematics is a subject which students at the senior secondary school level of Education in Nigeria must pass with at least a credit in external examinations. There is however no gainsaying that many students experience much difficulty when solving mathematical problems. Hence, Mathematics has never received the pride of place in the list of subjects that students usually pass (Akanni, 2016). For instance, the results of students who sat for the Senior Secondary Certificate Examination (May/June) in Nigeria in the period of 2004-2014 showed that majority of the students failed Mathematics woefully. The result revealed that 31.82% passed Mathematics with at least a credit (West African Examination Council Research Division Annual Reports, 2014). Furthermore, a close examination of the performance of students in Mathematics in May/June of 2015 and 2016 respectively showed that 65.82% and 61.32% obtained D_7-F_9 respectively in Mathematics (West African Examination Council, 2016). Unfortunately, the performance of students in Mathematics has continued to sink over the years. The performance of students who sat for the 2022 May/June of the WASSCE also fell below expectation as only 48.69% of the candidates who registered for the examination obtained credits in five subjects including Mathematics and English Language. This woeful performance of students in Mathematics is not only limited to external examinations. Galadima and Yusha'u (2007) conducted a research on the performance of students in Mathematics in Senior Secondary Schools located in Sokoto state, Nigeria. Galadima and Yusha'u (2007) based their research on Mathematical concepts, principles, terms and symbols in algebra, trigonometry and statistics. The research was limited to Senior Secondary (SS) II students who have covered adequate content of algebra, trigonometry and statistics of SS II mathematics curriculum. Three hundred and sixty eight students were involved in the research. A standardised test comprising of questions based on Algebra, Trigonometry and Statistics was used to elicit data from the students on their performance in Mathematics. The data collected were analyzed using statistical tools such as mean, standard deviation and one-way analysis of variance (ANOVA). The research showed that the students performed poorly in the standardised test with a total mean score of 23.02. Adediwura and Agunbiade (2015) also noted that students who are above average perform below expectation in Mathematics in Osun state. This frequent drop in the performances of students in Mathematics have been attributed to students' negative attitude towards the subject, the use of the traditional chalk and board as the only teaching aid, inadequate follow up activities after classes, inadequate parental support amongst others (Eze and Ikpe, 2023). Consequently, there is a far reaching effect on the future career choices of students as they are denied the opportunity to proceed to tertiary institutions of learning and the privilege to develop their potentials optimally.

5.0 Effects of Augmented Reality on Students Academic Performance in Mathematics

The word Augmented is a term that is derived from a Latin word “augere” which means to increase or add to. Augmented Reality (AR) as its name implies is a technology that enhances or augments the real world with digital information. In other words, AR allows people to interact with virtual objects as if they are physically present. From the foregoing, AR can simply be defined an interactive experience that combines the real world and computer generated contents (Shweta, 2021). It involves the integration of digital information with a user’s environment in real time. AR is used to deliver sensory information such as sounds and visual elements to a user through devices which include wearable AR glasses, tablets and smart phones. This information is used to change the user’s perception of the real world. AR has been deployed in diverse human activities which include medicine, design and modeling, gaming and entertainment industry, advertising, tourism and education (Cevikbas et al., 2023). AR, although a nascent technology in education is a valuable tool that is used to assist students to have a mastery of a subject by creating a more immersive and interactive environment which makes them to acquire new learning skills. AR also helps teachers to show virtual examples of concepts and also add gaming elements which enables students to learn and memorise concepts faster.

Diverse authors have worked on the impact of AR on the academic performance of students in Mathematics. These authors span across various continents such as North America, South America, Australia, Asia and Europe (Cevikbas et al., 2023). Their researches were focused on geometry, algebra, calculus, probability as well as financial and school mathematics. Several authors such as Jesionkowska (2020), Chen (2019) and Rodríguez et al. (2021) indicated that AR have a significant impact on the visual thinking skills of students learning Mathematics by providing rich visualizations in both physical and virtual environments. This according to the authors assisted the students to develop their spatial abilities. In addition, Demitriadou (2022), Monteiro (2021) and Ahmad et al. (2020) emphasized that AR boosted students’ learning interest, motivation and curiosity with respect to mathematics learning. Furthermore, Bujak et al. (2013) and Stranger-Johannessen (2018) are of the view that students who learn mathematics through AR demonstrated enthusiasm and derived enjoyment in the learning process. Again, Chen (2019) revealed that AR helps students to reduce anxiety and stress during mathematics lessons.Arican and Özçakir (2021) carried out a research on the use of AR for supporting students’ motivation, understanding, and performance in geometry. The aim of the research was to use AR for the improvement of spatial reasoning abilities and comprehension of geometric shapes and their properties. The result of the research showed that AR has the ability to improve the abstract and practical aspects of students' geometric thinking skills.Luki et al. (2024) investigated the applications of AR in Mathematics Education. The methods used for this research included bibliometric and content analysis of existing academic literatures from 2014-2023. In addition, the research deployed the use of co-occurrence and thematic map analysis to reveal the emerging research topics associated with AR. The results of the study showed that most researches associated with the use AR in Mathematics include geometry and problem-solving skills. Furthermore, the study showed that AR offers visual and interactive experiences which help students to comprehend complex concepts in Mathematics which thereafter improves their learning outcomes.

Ghanbarzadeh and Ghapanchi (2020) emphasised the importance of AR in higher education especially in subjects like Mathematicsto enhance learning process. Hsieh and Chen (2019) focused on the intervention of AR video towards problem-solving skills in Mathematics. The aim of the research was to develop a mobile AR system for remedial teaching of compound cube surface area. The authors revealed that students taught with the AR system showed a substantial improvement in their performance in Mathematics .Unfortunately, as at the time of this research,very limited researches have conducted a to investigate the impact of AR on the academic performance of students in Mathematics in Africa. Hence, the need for this research.

6.0 Methodology

This section discussed the materials and methods adopted for the research.

6.1 Study Area

The research covered the two Local Government Areas (LGAs) in Ile-Ife, Osun State, which is located in the South Western part of Nigeria. The two LGAs are Ife East and Ife Central.

6.2 Research Design

This research adopted the descriptive survey research design. The descriptive survey enabled the researchers to obtain information from a representative sample comprising Senior Secondary I, II and III students in both public and private secondary schools in Ile-Ife. The design made it possible for the researchers to use a Mathematics Performance Test (MPT) and a questionnaire to determine the level of students' performance in Mathematics when taught with the traditional chalk and talk method and Augmented Reality as well as obtain in-depth information on the effect and challenges of Augmented Reality on the academic performance of senior secondary schools in Mathematics in Ile-Ife, Nigeria.

6.3 Population

The population for the research comprised students in Senior Secondary I, II and III in Ile-Ife, Osun State. The research population consisted of both boarding and day students and also single sex and co-educational school student in both public and private schools.

6.4 AR Intervention

The study focused on the performance of students in various topics in Mathematics which include geometry, algebra, measurements, number bases, indices and logarithm. This is because these Mathematical concepts can be easily enhanced by visualisation or interactive elements. Devices such as tablets, AR Headsets, Smart glasses, Holographic AR Display and ARCore were deployed for the study. Students were made to be familiarised with the devices and group work where students create AR models was encouraged. Figure 2 shows an illustration of AR intervention in a typical classroom.

Figure 2: An illustration of AR intervention in a typical classroom (School Tech Solution, 2024)

6.5 Sample and Sampling Techniques

Stratified sampling technique was used for the research. The stratification index is the method of teaching. The students were grouped into two: those taught by the traditional chalk and talk method and those taught by the use of AR. Twenty public and 20 private schools were purposively selected for the research giving a total of 40 schools. The schools were selected purposively because this sampling technique saves time and it is cost effective. The sample consisted of students in their intact classes which were selected at random. A total of 1341 students comprised the sample size. Seven hundred and nine were taught with AR while 632 were taught with the traditional chalk and talk method.

6.6 Research Instruments

Two research instruments were used to collect data for the research. These include a Mathematics Performance Test (MPT) and an Augmented Reality Participation Questionnaire (ARPQ). The MPT was used to elicit data from the students on their performance in Mathematics. The MPT consists of fifty multiple choice questions ranging from algebra, geometry, statistics and trigonometry. The questions were selected from WAEC past question of 2022. The students were given four (4) options for each of the questions ranging from A-D. The students were scored on a 50-point scale and the average score for the test was 25 points. The ARPQ was designed by the researcher to obtain information from the senior secondary school students taught by AR method on the effects of AR on their performance in the MPT as well as the challenges experienced during the AR based mathematics lessons. The ARPQ consists of four sections. Section A solicited information on the demographic details of the respondents such as age, gender, class, name of school and school type while Section B solicited information of the level of students of students' performance in Mathematics in the MPT. Section C solicited information of the effects of AR on the performance of the students in Mathematics while Section D elicited information on the challenges of AR on the performance of the students in Mathematics.

6.7 Validity of the Instruments

The content and face validity of the MPT were carried out using expert opinions of lecturers from the Department of Mathematics, Adeyemi Federal University of Education, Ondo, Nigeria while the content and face validity of the ARPQ were carried out using expert opinions of lecturers from the Department of Computer Science, Adeyemi Federal University of Education, OndoNigeria.

6.8 Reliability of the Instruments

The MPT was administered to 30 SS I, II and III students in one of the selected secondary schools in Ile-Ife. After an interval of two weeks, a retest of the instrument was carried out on the same respondents. The results were subjected to reliability analysis. The Pearson's Product Moment Correlation (PPMC) test was used to measure the reliability of the instrument. In addition, the ARPQ was administered to 30 SS I, II and III students in one of the selected secondary schools in Ile-Ife. The Cronbach's Alpha Reliability Co-efficient was used to measure the reliability and the internal consistency of the instrument.

6.9Data Analysis

The data collected through the MPT were analyzed using Analysis of Variance (ANOVA) while the data collected through the ARPQ was analyzed using the simple linear regression.

7.0 Results

In this section, results are presented on the basis of the data collected and analysed in respect of the research questions and the hypotheses generated.

7.1 Research Question One

What is the level of students' level of students' performance in Mathematics when taught with Augmented Reality in senior secondary schools in Ile-Ife, Nigeria?

In answering this question, items on the Augmented Reality Participation Questionnaire (ARPQ) were used to elicit data from the students on their performance in Mathematics. The data collected were analysed using frequency counts and simple percentages. Table 1 shows the percentage distribution of students' level of performance in Mathematics when taught with Augmented Reality in senior secondary schools in the study area.

Table 1: Percentage Distribution Of Students' Level Of Performance In Mathematics When Taught With Augmented Reality In Senior Secondary Schools In Senior Secondary Schools In The Study Area

Level of Performance	**Frequency/Percentage of AR**
Excellent	383 (54.00%)
Very Good	254 (35.80%)
Good	54 (7.60%)
Fair	10 (7.09)

Poor	8(1.13%)
Total	709 (100%)

The result shows that a total of 709 students were taught with AR method. Three hundred and eighty three (54.00%) performed excellently in Mathematics when taught with AR method, 254 students (35.80%) performed very good in Mathematics when taught with AR method, the performance of 54 students (7.60%) was good in Mathematics when taught with AR method, The performance of 10 students (7.09%) was fair in Mathematics when taught with AR method while 8 students (1.13%) performed poorly in Mathematics when taught with AR method in the study area.

7.2 Research Question Two

Further analysis of the responses based on the effect of Augmented Reality on the academic performance of senior secondary schools in Mathematics in Ile-Ife, Nigeria is presented in Table 2. In answering this question, items on the Augmented Reality Participation Questionnaire (ARPQ) were used to elicit data from the students on the effect of Augmented Reality on their academic performance in Mathematics in the study area.

Table 2: Percentage Distribution of the effect of Augmented Reality on the academic performance of senior secondary schools in Mathematics in the Study Area

S/N	Effect of Augmented Reality on the Academic Performance of Senior Secondary Schools	Frequency/Percentage
1	enhances mathematical creativity	635 (89.56%)
2	reduces tension, fear, apprehension and anxiety of solving Mathematical problems	679 (95.77%)
3	makes mathematics simple due to the integration of games, videos and animation into the learning process	700(98.73%)
4	increases knowledge retention rate	699(98.59%)
5	facilitates the active participation of students in the learning of Mathematics	709(100%)

The result shows that out of the 709 students who were taught with the AR method, 635 students representing 89.56% of the total population reported that AR enhances mathematical creativity, 679 students (95.77%) reported that AR reduces tension, fear, apprehension and anxiety of solving Mathematical problems, 700 students (98.73%) believes that AR makes mathematics simple due to the integration of games, videos and animation into the learning process, 699 students (98.59%) reported that AR increases knowledge retention

rate while all the students(100%) are of the view that AR facilitates the active participation of students in the learning of Mathematics.

7.3 Research Question Three

The responses of the respondents based on the challenges of Augmented Reality on the academic performance of senior secondary schools in Mathematics in Ile-Ife, Nigeria are presented in Table 3. In answering this question, items on the Augmented Reality Participation Questionnaire (ARPQ) were used to elicit data from the students on the effect of Augmented Reality on their academic performance in Mathematics in the study area.

Table 3: Percentage Distribution of the challenges of Augmented Reality on the academic performance of senior secondary schools in Mathematics in the Study Area

S/N	Challenges of Augmented Reality on the Academic Performance of Senior Secondary Schools	Frequency/Percentage
1	erratic power supply	709(100%)
2	high cost of procuring and maintaining AR devices	709(100%)
3	inadequate/lack knowledge and skills to operate AR devices	709(100%)
4	discouragement as a result of non-satisfaction of the user interface	689 (97.17)

The result shows that out of the 709 students who were taught with the AR method, all the students representing 100.00% of the total population reported that erratic power supply can hinder the effective use of AR devices to teach Mathematics in the study area. Similarly, all the students (100.00%) are of the view that high cost of procuring and maintaining AR devices can impede the use of the devices to teach and learn Mathematics in the study area. A hundred percent (100.00%) of the students reported that inadequate/lack of knowledge and skills to operate AR devices can serve as an impediment to the teaching and learning of Mathematics in the study area while 97.17% of the respondents reported that a poorly designed user interface can discourage students from participation in an AR driven classroom.

7.4 Hypothesis One

In answering this hypothesis, items on the Mathematics Performance Test (MPT) were used. The data collected were analysed using Analysis of Variance (ANOVA). Table 4 shows the mean score of the students' performance in the MPT. The result shows that the mean score of the level of students' level of students'

performance in Mathematics when taught with Augmented Reality in senior secondary schools in Ile-Ife, Nigeria is 37.63 while the mean score of the students taught with traditional chalk and talk method is 25.41.

Table 4: Mean Scores of Students' Performance in the MPT

Teaching Method	Sum of Scores	Total Number of Students	Mean of Scores
AR	26,678	709	37.63
Traditional Chalk And Talk Method	16,056	632	25.41
	42734	1341	63.04

Table 5 shows the Analysis Of Variance on the level of students' level of students' performance in Mathematics when taught with Augmented Reality in Senior Secondary Schools in Ile-Ife, Nigeria.

Table 5 below shows that there is a significant influence of AR on the academic performance of students in Mathematics in the study area ($F = 22.46$, $p < 0.05$).This means that students who are taught with traditional chalk and talk method do not perform better in Mathematics than students taught with AR in the study area. Therefore, the null hypothesis which states that students who are taught with traditional chalk and talk method do not perform better in Mathematics than students taught with AR in the study area is rejected.

Table 5: Analysis Of Variance on Students who are taught with traditional chalk and talk method do not perform better in Mathematics than students taught with AR in the study area

Source of Variation	Sum of Squares	Degree of freedom	Mean Sum of Squares	F	Sig. *p*
Between groups	29860.25	1	29860.25	22.46	0.000
Within groups	2659.5	2	1329.75		
Total	28518.75	3	301419.8		

7.5 Hypothesis Two

In answering this hypothesis, items on the Mathematics Performance Test (MPT) were also used. The data collected were analysed using Linear Regression. Table 6 shows how the level of students' participation in the learning of mathematical concepts with AR significantly affects their performance in Mathematics in the study area.

Table 6: Analysis of how the Level of Students Participation in the Learning of Mathematical Concepts with AR Significantly Affects Their Performance in Mathematics In The Study Area.

R	R^2	Adjusted R^2	Source of Variation	Sum of Squares	df	Mean Sum of Squares	F	Sig. *p*
0.710	0.510	0.200	Students' Level of Participation in the Learning of Mathematical Concepts with AR					
			Between Groups	5762.975	1	5762.975	243.6776	0.000
			Within Groups	16741.184	708	23.65		
			Total	22504.16	709			

Table 6 depicts that the co-efficient of determination (Adjusted R^2) is 0.20 which gives the proportion of variance as 20%. This implies that students' level of participation in thelearning of Mathematicalconceptswith ARsignificantly affects their performance in Mathematics in the study area. Table 6 also shows that the F-value ($F(1,708) = 243.677$) is significant at 0.05, ($p<0.05$).

8.0 Discussion

To the research question on the level of students' level of students' performance in Mathematics when taught with Augmented Reality in senior secondary schools in Ile-Ife, Nigeria, the result shows that level of students' level of students' performance in Mathematics when taught with Augmented Reality in senior secondary schools in Ile-Ife, Nigeria is excellent. This finding corroborates the findings of Demitriadou (2022), Monteiro (2021) and Ahmad et al. (2020) who emphasised that AR boosted students' learning interest, motivation, performance and curiosity with respect to Mathematics learning. The result on the research question two which states that "What isthe effect of Augmented Reality on the academic performance of senior secondary schools in Mathematics in Ile-Ife, Nigeria?" shows thatstudents who were taught with the AR method, reported that AR enhances mathematical creativity,reduces tension, fear, apprehension and anxiety of solving Mathematical

problems. The result from the study also revealed that AR makes Mathematics simple due to the integration of games, videos and animation into the learning process and AR increases knowledge retention rate as well as facilitates the active participation of students in the learning of Mathematics. This is in line with the studies of Stranger-Johannessen (2018) and Chen (2019) who are of the view that students who learn Mathematics through AR demonstrated enthusiasm and derived enjoyment in the learning process. The result of the research question three which states that "What are the challenges of Augmented Reality on the academic performance of senior secondary schools in Mathematics in Ile-Ife, Nigeria?" shows that erratic power supply, high cost of procuring and maintaining AR devices and inadequate/lack of knowledge and skills to operate AR devices can serve as an impediment to the teaching and learning of Mathematics in the study area. This is in consonance with the research of Michael (2015) who is of the view that the deficiency of AR as instructional materials leads to the decline in the academic performance of students in Mathematics.

9.0. Conclusion

This study examined the impact of Augmented Reality on the learning outcomes of senior secondary school students in Ile-Ife, Nigeria and also investigated the level of students' performance in Mathematics when taught with the traditional chalk and talk method and Augmented Reality in senior secondary schools in Ile-Ife, Nigeria, and also examined the challenges of Augmented Reality on the academic performance of senior secondary schools in Mathematics in Ile-Ife, Nigeria.The results obtained from the study showed that the level of students' performance in Mathematics when taught with the Augmented Reality in senior secondary schools in Ile-Ife, Nigeria is high. The study also revealed that the effect of Augmented Reality on the academic performance of senior secondary schools in Mathematics in Ile-Ife, Nigeria include facilitation of mathematical creativity,reduction of tension, fear, apprehension and anxiety of solving Mathematical problems and increase in knowledge retention rate of students undertaking Mathematics in Senior Secondary Schools in the study area. The study also showed that some of the challenges of Augmented Reality on the academic performance of senior secondary school students in Ile-Ife, Nigeria include erratic power supply, high cost of procuring and maintaining AR devices and inadequate/lack knowledge and skills to operate AR devices.

10.0 Future Research Directions

An in-depth research on the effectof Augmented Reality on student learning outcomes in higher institutions of learning in Nigeria can be carried out in future researches. Researches on the impact of AR on students' learning outcomes in Senior Secondary Schools can also be carried out in other states in Nigeria.

Disclaimer (Artificial intelligence)

Option 1: Generative AI was not deployed for this research

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1. Generative AI was not deployed for this research

2.

3.

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Supplementary Materials

AUGMENTED REALITY PARTICIPATION QUESTIONNAIRE (ARPQ)

The purpose of the ARPQ is to obtain information from the senior secondary school students taught by Augmented Reality **(**AR) method on the effects of AR on their performance in the Mathematics Performance Test (MPT) as well as the challenges experienced during the AR based mathematics lessons. The ARPQ consists of four sections. Section A will solicit information on the demographic details of the respondents such as age, gender, class, name of school and school type while Section B solicits information on the performance of students in the MPT. Section C solicits information of the effects of AR on the performance of the students in Mathematics while Section D elicits information on the challenges of AR on the performance of the students in Mathematics. Kindly supply the needed information as applicable to you and tick where applicable. All information supplied will be kept confidential and used for research purposes only.

SECTION A: DEMOGRAPHIC INFORMATION OF THE RESPONDENTS

1. Name of School:----------
2. School Type: public ☐ private ☐
3. Local Government: Ife Central ☐ Ife East ☐
4. Age: 13-15 ☐ 18-20 ☐ Above 20 ☐
5. Sex……
6. Class……..

SECTION B: LEVEL OF STUDENTS' PERFORMANCE IN THE MATHEMATICS PERFORMANCE TEST (MPT)

What is your level of performance in the Mathematics Performance Test (MPT). Kindly tick (√) appropriately

Level of Performance	**Tick where Appropriate**

Excellent	
Very Good	
Good	
Fair	
Poor	

SECTION C: EFFECTS OF AR ON THE PERFORMANCE OF THE STUDENTS IN MATHEMATICS

What are the effects of Augmented Reality on your Performance in the MPT?

S/N	Effect of Augmented Reality on the Academic Performance of Senior Secondary Schools	Tick where Appropriate
1	enhances mathematical creativity	
2	reduces tension, fear, apprehension and anxiety of solving Mathematical problems	
3	makes mathematics simple due to the integration of games, videos and animation into the learning process	
4	increases knowledge retention rate	
5	facilitates the active participation of students in the learning of Mathematics	
6	Others	

SECTION D: Challenges of AR on the Performance of the Students in Mathematics

What are some of the challenges of Augmented Reality on your Performance in the MPT?

S/N	Challenges of Augmented Reality on the Academic Performance of Senior Secondary Schools	Tick where Appropriate
1	erratic power supply	
2	high cost of procuring and maintaining AR devices	
3	inadequate/lack knowledge and skills to operate AR devices	
4	discouragement as a result of non-satisfaction of the user interface	
5	Others	

APPENDIX II

MATHEMATICS PERFORMANCE TEST (MPT)

The Mathematics Performance Test (ELPT) is based on 2022 WAEC questions. Its purpose is to test students on their performance in Mathematics. The MPPT contains fifty questions. These questions are to test your basic skills in algebra, geometry, statistics and other aspects of Mathematics

1. Evaluate, correct to four significant figures, (573.06 x 184.25).

A. 105600.00
B. 105622.00
C. 105500.00
D. 105632.00

2. Change 432five to a number in base three
A. 10100three
B. 11100three
C. 11101three
D. 10110three

3. Given that A and B are sets such that n(A) = 8, n(B)=12 and n(AnB) =3, find n(AuB).
A. 15
B. 17
C. 20
D. 23

4. If √24 + √96 - √600 = y√6, find the value of y
A. 4
B. 2
C. -2
D. -4

5. Evaluate 23 x 54 (mod 7)
A. 2
B. 3
C. 5
D. 6

6. If 43x = 16x+1, find the value of x
A. 2
B. 3
C. 4
D. 5

7. A weaver bought a bundle of grass for $ 50.00 from which he made 8 mats. If each mat was sold for $ 15.00, find the percentage profit.
A. 240%
B. 140%
C. 120%
D. 40%

8. Find the 17term of the Arithmetic Progression (A.P):-6,-1,4
A. -91
B. -86
C. 74
D. 79

9. M varies directly as n and inversely as the square of p. If M= 3 when n = 2 and p = 1, find M in terms of n and p.
A. 3n2p2
B. 2n3p2
C. 2n3p
D. 3n22p2

10. If a = 3 and b = -7, find the value of 5b+(a+b)2(a−b)2
A. 0.51
B. 0.91
C. -0.19
D. -0.51

11. Three boys shared D 10,500.00 in the ratio 6:7:8. Find the largest share.
A. 4000

B. 5000
C. 4500
D. 3500

12. The length of a piece of stick is 1.75 m. A boy measured it as 1.80 m. Find the percentage error
A. 447
B. 267
C. 279
D. 479

13. If $5x + 3y=4$ and $5x-3y= 2$, what is the value of $(25x^2- 9y^2)$
A. 20
B. 16
C. 2
D. 8

14. Mary has $ 3.00 more than Ben but $ 5.00 less than Jane. If Mary has $ x, how much does Jane and Ben have altogether?
A. $(2x-8)
B. $(2x+8)
C. $(2x-2)
D. $(2x+2)

15. Consider the statements:
p: Stephen is intelligent
q: Stephen is good at Mathematics
If $p \Rightarrow q$, which of the following is a valid conclusion?
A. If Stephen is good at Mathematics, then he is intelligent
B. If Stephen is not good at Mathematics, then he is not intelligent
C. If Stephen is not intelligent, then he is not good at Mathematics
D. If Stephen is not good at Mathematics, then he is intelligent

16. What value of p will make $(x^2 - 4x + p)$ a perfect square?
A. -2
B. 16
C. 4
D. -8

17. Find the value of x such that $1x +43x- 56x + 1 = 0$
A. 16
B. 14
C. −32
D. −76

18. Make t the subject of $k = mt−pr$
A. k2r+pm2
B. k2r+pm2m2
C. k2r−pm2
D. k2r+p2m2

19. An exterior angle of a regular polygon is 22.5°. Find the number of sides.
A. 13
B. 14
C. 15
D. 16

20. In the diagram, ∠POQ = 150 and the radius of the circle PSQR is 4.2cm. [take $\pi = 22/7$]. What is the length of the minor arc?
A. 11cm
B. 15.4cm
C. 17.64cm

D. 23.10cm

21. Find the area of the sector OPSQ
A. 15.40cm^2
B. 17.64cm^2
C. 23.10cm^2
D. 32.34cm^2

22. A ladder 6m long leans against a vertical wall at an angle 53º to the horizontal. How high up the wall does the ladder reach?
A. 3.611m
B. 4.521m
C. 4.792m
D. 3.962m

23. A cylinder, opened at one end, has a radius of 3.5cm and height 8cm. calculate the total surface area
A. 126.5cm2
B. 165.0cm2
C. 212.0cm2
D. 214.5cm2

24. In the diagram, ∠ZWZY and WYX are right angles. Find the perimeter of WXYZ.
A. 30cm
B. 32cm
C. 35cm
D. 37cm

25. The length of a rectangle is 10 cm. If its perimeter is 28 cm, find the area
A. 30cm2
B. 40cm2
C. 60cm2
D. 80cm2

26. A boy 14 m tall, stood 10m away from a tree of height 12 m. Calculate, correct to the nearest degree, the angle of elevation of the top of the tree from the boy's eyes.
A. 70º
B. 47º
C. 19º
D. 8º

27. Given that sin (5x-28)° = cos (3x-50)", 0°≤ x ≤ 90°, find the value of x.
A. 39
B. 32
B. 21
D. 14

28. In the diagram, MNR is a tangent to the circle centre O at N and ∠NOS = 108°. Find ∠OSN
A. 72°
B. 32°
C. 36°
D. 18°

29. Find ∠SON
A. 36º
B. 42º
C. 54º
D. 72º

30. Mrs Gabriel is pregnant. The probability that she will give birth to a girl is 1/2 and with blue eyes is 1/4. What is the probability that she will give birth to a girl with blue eyes?
A. 1
B. 34
C. 18

D. 14

31. The mean of a set of 10 numbers is 56. If the mean of the first nine numbers is 55, find the 10th number.

A. 75
B. 65
C. 55
D. 45

32. Simplify 2−18m21+3m

A. 2[1+3m]
B. 2[1-3m]
C. 2[1-3m2]
D. 2[1+3m2]

33. In the diagram, triangle MNR is inscribed in circle MNR, and line PQ is a straight line. ∠MRN = 41 and = 141, find ∠QNR

A. 39º
B. 80º
C. 110º
D. 141º

34. Solve y+24- y−13> 1

A. y < -10
B. y < -2
C. y < 2
D. y < 10

35. The age (years) of some members in a singing group are: 12, 47, 49, 15, 43, 41, 13, 39, 43, 41 and 36. Find the lower quartile

A. 12
B. 13
C. 15
D. 20

36. The age (years) of some members in a singing group are: 12, 47, 49, 15, 43, 41, 13, 39, 43, 41 and 36. Find the mean

A. 33.35
B. 35.54
C. 34.45
D. 36.44

37. Find the correct to two decimal places, the volume of a sphere whose radius is 3cm. [Take π = 227]

A. 72.57cm3
B. 88.12cm3
C. 10529cm3
D. 113.14cm3

38. The lengths of the parallel sides of a trapezium are 9cm and 12cm. If the area of the trapezium is 105cm2, find the perpendicular distance between the parallel sides.

A. 5cm
B. 7cm
C. 10cm
D. 15cm

39. Find the volume of a cone of radius 3.5cm and vertical height 12cm. [Take π = 22/7]

A. 15.5cm3
B. 21.0cm3
C. 142cm3
D. 154cm3

40. A local community has two newspapers: the morning tomes and the evening dispatch. The morning times is read by 45% of the households. The Evening Dispatch is read by 60% of the households. Twenty percent

of the households read both papers. What is the probability that a particular household reads at least one paper?

A. 0.45
B. 0.65
C. 0.85
D. 0.95

41. A rectangle with width 34 cm and area is 338cm^2. Find the length

A. 6cm
B. 412cm
C. 2 58cm
D. 12cm

42. The mean of two numbers x and y is 4. Find the mean of four numbers x, 2x, y and 2y

A. 2
B. 4
C. 6
D. 8

43. The straight line y = mx - 4 passes through the point(-4,16). Calculate the gradient of the line

A. -5
B. -3
C. 3
D. 5

44. If the equations $x^2 - 5x + 6 = 0$ and $x + px + 6 = 0$ have the same roots, find the value of p.

A. 5
B. 6
C. -5
D. -6

45. A trader made a loss of 15% when an article was sold. Find the ratio of the selling price : cost price

A. 3:20
B. 3:17
C. 17:20
D. 20:23

46. Given that $\log_3 27 = 2x + 1$, find the value of x.

A. 0
B. 1
C. 2
D. 3

47. Solve $6x^2 = 5x - 1$

A. x = 2,3
B. x = 0,3
C. x = 12, 13
D. x = 12, −13

48. Given that (7 -2x), 9, (5x + 17) are consecutive terms of a Geometric Progression (G. P) with common ratio, r>0, find the values of x.

A. x = 2
B. x = 5
C. x = 12
D. x = 7

49. Given that y =(prm−p2r)−32

A. (y+32)/p(m-p)
B. y-32/p+m
C. y/32pm
D. 32/ypm

50. A chord subtends an angle of 72º at the centre of a circle of radius 24.5m. Calculate the perimeter of the minor segment. [Take $\pi = 22/7$]

A. 108
B. 72
C. 180
D. 90