ISSN: 2713 - 2822
Volume 13, Number 2, 2026
International Journal of Educational Research & Practice

EFFECT OF VIRTUAL REALITY ON BASIC SCHOOL PUPILS' ACHIEVEMENT IN MATHEMATICS IN JALINGO EDUCATION ZONE OF TARABA STATE.

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Abstract

This study investigated the effect of Virtual Reality Learning Environment (VRLE) on Basic School pupils' achievement in Mathematics in Jalingo Education Zone of Taraba State, Nigeria. The study was guided by three objectives, three research questions, and three null hypotheses. The study was anchored on Constructivist Learning Theory by Piaget (1952) and Experiential Learning Theory by Kolb (1984). A quasi-experimental research design, specifically the pre-test, post-test, non-equivalent control group design, was adopted. The population comprised 9,968 Basic Five pupils in 56 public primary schools in Jalingo Education Zone during the 2025/2026 academic session. A sample of 190 pupils consisting of 100 males and 90 females was selected through simple random sampling techniques from three public primary schools. The instrument used for data collection was the Virtual Reality Achievement Test (V-RAT), which was validated by experts in Mathematics Education, Educational Technology, and Measurement and Evaluation. Data collected were analyzed using mean and standard deviation to answer the research questions, while Analysis of Covariance (ANCOVA) was used to test the hypotheses at 0.05 level of significance. The findings revealed that pupils taught Mathematics using Virtual Reality Learning Environment achieved higher mean scores (M = 20.22) than those taught using the Conventional Teaching Method (M = 18.27). The ANCOVA result showed a significant difference in achievement between pupils exposed to VRLE and those taught conventionally ($F = 10.359$, $p = .002$). The study further revealed a significant gender difference in achievement among pupils exposed to VRLE ($F = 12.610$, $p = .001$). In addition, a significant interaction effect of learning environment and gender on pupils' mathematics achievement was found ($F = 35.633$, $p < .05$). The study concluded that Virtual Reality Learning Environment significantly enhances pupils' achievement in Mathematics and that gender moderates its effectiveness. It was recommended, among others, that mathematics teachers should adopt Virtual Reality Learning Environments in classroom instruction, educational authorities should organize regular training programmes on the use of VR technologies, and government should provide the necessary technological facilities to support the integration of Virtual Reality into mathematics teaching and learning.

Keywords: ***Virtual Reality Learning Environment, Mathematics Achievement.***

1.1 Introduction

Mathematics is generally regarded as an essential discipline in terms of its contributions to the scientific, technological, and socioeconomic development of nations. It equips the learners with the competencies of logical reasoning, problem-solving, critical thinking, and mathematical analysis that are crucial for their daily activities as well as career life. UNESCO (2023) states that mathematics education acts as a key element in innovation, technological development, and national development. Mathematics has occupied a very

important place in the Nigerian educational curriculum due to its application in STEM. However, despite its importance, poor performance by the pupils in mathematics has been recorded in internal and external examinations. This continued poor performance in mathematics among pupils has led to the quest for instructional innovations in teaching mathematics.

New instructional models have gained more significance in tackling the challenges experienced during the process of teaching and learning mathematics. Many educational researchers have called for the development of learner-centered instructional models that involve the use of technology in fostering effective learning processes. According to OECD (2023), educational technologies have revolutionized classroom teaching through offering students an interactive platform for learning that helps them to understand complex concepts effectively. One of the emerging technologies that have attracted many researchers' interests in education is the Virtual Reality (VR) technology. The widespread adoption of VR technology in education has raised much interest in exploring its effectiveness in the learning of mathematics by students.

Virtual reality refers to the three-dimensional environment created by computers to allow users to engage with objects and situations similar to those found in real life. Virtual Reality provides immersive and interactive activities that enable learners to make visualizations, manipulations of objects, and participation in the learning processes. According to Radianti et al. (2020), Virtual Reality refers to the technology used to create an immersive digital environment where users can interact with simulated objects and situations. Contemporary research indicates that virtual reality contributes positively to increased engagement, understanding, and memory of learned information among learners in different disciplines. This capability of Virtual Reality makes it especially pertinent to mathematics instruction.

Mathematics tends to be considered a complicated and abstract discipline since many aspects of mathematics cannot be easily observable or tangible in practical scenarios. Mathematics principles that involve visualizing or manipulation of abstract concepts in geometric, measuring, algebraic, and spatial relationships prove hard for many pupils. In accordance with Bicer et al. (2022), the struggle that most students face in comprehending some of the abstract mathematics principles leads to academic underachievement. The conventional teaching approaches that focus primarily on verbal instruction and bookwork fail to address these challenges effectively. Therefore, educators have been adopting technology-based solutions such as Virtual Reality for mathematics learning.

Implementation of Virtual Reality in math education makes possible the application of simulations and visualization to teach math concepts. In virtual reality apps, students will be able to manipulate shapes, interact with 3D objects, and solve problems through immersion. Studies conducted by Kavanagh et al. (2022) found that students who were taught using VR-based approaches displayed improved levels of engagement and understanding as compared to students in traditional classes. In addition, according to Makransky and Petersen (2021), virtual reality-based immersive learning environments enhance cognitive processes and increase academic success among students. The ability of VR to facilitate improved conceptualization makes it important to study the effects of VR on academic performance.

Achievement in academia denotes the degree of success learners achieve in terms of educational goals set out for them, as assessed using examination methods and tests

among others. The achievement of mathematics can be used as an effective measure of the efficiency of instructional strategies provided to the learners. There are several empirical studies showing the positive linkages between educational technology and academic achievement. Jensen and Konradsen (2023) demonstrated that the integration of Virtual Reality into learning enhanced achievement in both mathematics and science subjects. While these studies point out the efficiency of VR on achievement, little empirical evidence exists from developing countries, especially Nigeria.

Despite many reforms and innovations carried out by the educational authorities in the Nigerian system, mathematics performance among students in basic schools has remained one of the most troubling issues. The reports by the National Examinations Council and other agencies in the education sector keep pointing out poor performances of learners in the mathematics subject. The issue has been traced to causes such as lack of instructional resources, pedagogical methods that involve excessive teacher participation, low motivation levels of learners, and poor integration of technology into learning practices (Akinsola & Olowojaiye, 2022). With the rising popularity of online learning and technology-based educational innovations, it has become increasingly imperative to analyze the roles played by new technologies, such as virtual reality, in enhancing mathematics achievement among learners. The Jalingo Education Zone of Taraba State is made up of a number of basic schools, both government-owned and privately owned, that teach children from varied academic and learning backgrounds. Although the efforts being put forth by the government towards improving the quality of education via reforms and development programs meant for teachers, the issue of poor achievement levels of pupils in mathematics persists within the zone. Reports from the field show that pupils face some challenges in comprehending mathematical concepts, which result in low achievement levels as well as a lack of enthusiasm towards mathematics. Another aspect related to the use of modern educational technology like Virtual Reality among basic schools within the zone has not been exploited much.

It has become very significant to conduct research on the impact that Virtual Reality can have on learners' performance in Mathematics classes because there has been growing interest in developing innovative and effective methods of teaching learners. Although studies carried out in advanced nations have shown that virtual reality technology enhances learners' performance in Mathematics, the efficacy of virtual reality among learners in basic schools in Jalingo Education Zone of Taraba State has not been extensively investigated. The effectiveness of virtual reality may be affected by a number of factors such as educational facilities, access to technology, teachers' capabilities, and learning environment. It is therefore essential to carry out research on the impact of virtual reality on the achievement of learners in mathematics in Jalingo Education Zone of Taraba State.

1.2 Statement of the Problem

Pupils' achievement in mathematics cannot be improved unless teachers adopt suitable methods and strategies of teaching the subject. In this modern age materials are common and readily available; the use of new technologies available such as virtual reality-based instruction which involves the use of games and simulations among others may likely have positive effect on school pupils' achievement. Mathematics is considered to be the foundation for all science subjects and courses. The achievement in mathematics subject places the pupils at advantage in excelling in all the science base subjects and

courses. Teaching of Mathematics involves the use of innovative approaches for achievement. However, the conventional mode of teaching mathematics in our schools is prevalent. Such teaching approach hinders the pupils from quick understanding and eventually affect their achievement in mathematics. Nigeria as a developing country needs innovation in teaching and learning process. Unfortunately, the teaching and learning of mathematics at all levels of the educational system in Nigeria can be described to be in a dismal state. It is the researcher's observation that those strategies and technologies are not being incorporated in the teaching approaches adopted by mathematics teachers among Basic schools mathematics in Jalingo Education zone. Based on this, the studied investigated the effect of virtual reality on basic five pupils' achievement in Jalingo Education zone of Taraba State, Nigeria.

1.3 The Purpose of the Study

The purpose of this study is to examine the effect of virtual reality on Basic School pupils' achievement in mathematics in Jalingo Education of Taraba State, Nigeria. The study seeks specifically to determine:

i. The effect of a virtual reality on the mean mathematics achievement scores of basic school pupils in Jalingo Education Zone.
ii. The difference in the academic performance of basic school pupils in virtual reality.
iii. The interaction effect of virtual reality and gender on the academic achievement of basic school pupils in Jalingo Education zone.

1.4 Research Question

The following research question were formulated to guide this study

1. What is the effect of a virtual reality on the mean mathematics achievement scores of basic school pupils in Jalingo Education Zone?
2. What is the difference in the mean mathematics achievement scores of male and female basic school pupils exposed to a virtual reality in Jalingo Education Zone?
3. What is the interaction effect of virtual reality and gender on the mean mathematics achievement scores of basic school pupils in Jalingo Education Zone?

1.5 Research Hypotheses

The following null hypotheses were formulated and tested at 0.05 level of significance.

H_{O1}: There is no significant difference in the mean mathematics achievement scores of basic school pupils taught using a virtual reality and those taught using the conventional teaching method in Jalingo Education Zone.

H_{O2}: There is no significant difference in the mean mathematics achievement scores of male and female basic school pupils exposed to a virtual reality in Jalingo Education Zone.

H_{O3}: There is no significant interaction effect of virtual reality versus conventional and gender on the mean mathematics achievement scores of basic school pupils in Jalingo Education Zone.

Theoretical Framework

The theoretical framework for this study is anchored on Constructivist Learning Theory propounded by Jean Piaget (1952)and Experiential Learning Theory developed by David Kolb (1984). These theories provide a sound foundation for understanding how Virtual Reality (VR) can influence pupils' achievement in mathematics by creating interactive and learner-centered environments that facilitate active knowledge construction and meaningful learning experiences.

Constructivist Learning Theory

Constructivist Learning Theory was developed by Jean Piaget (1952). The theory posits that learners actively construct knowledge through interaction with their environment rather than passively receiving information from teachers. According to Piaget, learning occurs when individuals assimilate new experiences into existing cognitive structures and accommodate these structures when faced with new information. The theory emphasizes active participation, exploration, discovery, and problem-solving as essential elements of effective learning. In the classroom, learners are encouraged to engage with instructional materials and learning activities that enable them to develop their own understanding of concepts. The relevance of Constructivist Learning Theory to this study lies in the fact that Virtual Reality provides an interactive learning environment where pupils can actively engage with mathematical concepts. Through Virtual Reality applications, pupils can manipulate three-dimensional objects, explore geometric shapes, and visualize abstract mathematical ideas in ways that are difficult to achieve through conventional teaching methods. Such interactions promote meaningful learning by enabling pupils to construct knowledge based on direct experiences. Consequently, Virtual Reality aligns with the principles of constructivism by transforming pupils from passive recipients of information into active participants in the learning process.

Furthermore, the theory suggests that learning is more effective when learners are involved in activities that encourage exploration and discovery. Virtual Reality-based mathematics instruction provides opportunities for pupils to investigate mathematical relationships, experiment with different problem-solving strategies, and receive immediate feedback on their actions. These experiences facilitate deeper understanding and retention of mathematical concepts, which may ultimately lead to improved academic achievement. Therefore, Constructivist Learning Theory provides a theoretical explanation for how Virtual Reality can enhance pupils' achievement in mathematics.

Experiential Learning Theory

Experiential Learning Theory was developed by David Kolb (1984). The theory proposes that learning is a process whereby knowledge is created through the transformation of experience. Kolb identified four stages of learning, namely concrete experience, reflective observation, abstract conceptualization, and active experimentation. According to the theory, effective learning occurs when learners progress through these stages by engaging in direct experiences, reflecting on those experiences, forming concepts, and applying what they have learned in new situations.

The application of Experiential Learning Theory to this study is evident in the immersive nature of Virtual Reality technology. Virtual Reality creates simulated environments that allow pupils to experience mathematical concepts in realistic and

interactive ways. For example, pupils can explore geometric figures, measure virtual objects, and solve mathematical problems within a simulated environment. These experiences provide concrete learning opportunities that enhance understanding and promote the development of mathematical skills. By interacting directly with mathematical concepts, pupils are able to move beyond rote memorization to meaningful comprehension. Moreover, Virtual Reality facilitates reflective observation and active experimentation by allowing pupils to test ideas, make corrections, and observe the outcomes of their actions in real time. This process enables learners to develop a deeper understanding of mathematical principles and improve their problem-solving abilities. The theory therefore supports the view that Virtual Reality can positively influence pupils' achievement by providing rich experiential learning opportunities that foster active engagement and conceptual understanding.

The combination of Constructivist Learning Theory and Experiential Learning Theory provides a comprehensive framework for explaining the effect of Virtual Reality on Basic School pupils' achievement in mathematics. Constructivist Learning Theory emphasizes the active construction of knowledge through interaction with learning environments, while Experiential Learning Theory highlights the importance of learning through direct experience and reflection. Virtual Reality embodies the principles of both theories by creating immersive, interactive, and learner-centered environments that enable pupils to explore, manipulate, and understand mathematical concepts more effectively. These theories collectively suggest that pupils exposed to Virtual Reality-based mathematics instruction are likely to achieve better learning outcomes than those taught through conventional teaching methods. The theories therefore provide a strong theoretical basis for investigating the effect of Virtual Reality on Basic School pupils' achievement in mathematics in Jalingo Education Zone of Taraba State.

Materials and Methods

The study adopted quasi-experimental design. Specifically, pre-test, post-test, non-equivalent control group design employed for the study. This is because there was no randomization of subjects into groups. The choice of this design is because it is difficult to take individual pupil at random from classes to participate in the study, six intact classes were used. Another reason for the adoption of the design is because the aims at establishing the effects of virtual reality on pupils' interest and academic achievement in mathematics. Class activities was not disrupted during the experimental treatment since intact classes was used.The study was carried out in Jalingo Education zone of Taraba State, Nigeria. The area is made up of both urban and rural settings. Jalingo is the capital of Taraba State, Northeast of Nigeria.The population of the study consists of all the 9,968 basic five pupils in 56 Public Primary Schools in Jalingo Education zone 2025/2026 academic session (Source Department of Planning, Research and Statistics EMIS Unit. Taraba State Universal Basic Education Board, 2026). The population of the basic five mathematics pupils consists of 4,501 males and 5, 467 females. The pupils' ages ranged from 9 to 11.A sample of (190) basic five pupils of public primary schools in Jalingo Education zone, consisting of 100 males and 90 females which was drawn from three (3) schools. Random sampling technique was used in selecting the schools for the study. In the first instance, three wards were selected from the ten (10) wards in Jalingo town of Jalingo Local Government Area of Taraba State through simple random sampling technique. Secondly, one (1) school from each of the three

selected wards was selected through simple random sampling technique which was randomly assigned experimental and control groups respectively.

The process is to pick three primary schools from Jalingo education zone using simple random sampling. The names of all the schools in Jalingo education zone were written on separate pieces of papers and be dropped into a hat and one school was picked randomly. The same technique was used to select three (3) school from Jalingo education zone for the study. The schools were randomly assigned to the control group and experimental group. Pre-test was administered to pupils in the intact classes to determine equivalent achievement. The sample for the investigation comprises 198 basic five pupils which was made up of male and female pupils in the three (3) schools selected. The number of pupils in the experimental and control groups are unequal because intact classes with different students' population maybe involved in the study.

Two instruments were developed by the researcher and validated by experts for the purpose of data collection. The instruments are: (a) Virtual Reality Achievement Test (V-RAT), and (b) Pupils Interest Questionnaire (PIQ). The study consists of two groups, one group was used for the virtual reality teaching and group two as control group. The administration of the instrument was carried out by the research assistants who assisted the researcher in intervention and data collection during the study.The data obtained were subjected to analysis for two different levels, Descriptive and inferential levels. The data obtained from the pre-test and post-test on students' interest and achievement tests were analyzed using mean and standard deviation for the research questions while Analysis of Covariance (ANCOVA) statistics was used to test the hypotheses at .05 level of significant.

Results

Research question one

What is the effect of a virtual reality learning environment on the mean mathematics achievement scores of basic school pupils in Jalingo Education Zone?

Table 1

Mean mathematics achievement Scores and Standard Deviations of basic school pupils in Jalingo Education Zone.

Group	N	Pre-test		Post-test		Mean
		$\overline{X}$	δ	$\overline{X}$	δ	Diff
VRLE	104	13.21	4.19	20.22	3.46	8.53
CTM	86	11.47	4.79	18.27	4.82	6.80
		1.74		3.47		1.73

Table 1 presents the mean mathematics achievement scores and standard deviations of basic school pupils who were taught mathematics using a Virtual Reality Learning Environment (VRLE) and those who were taught using the Conventional Teaching Method (CTM), based on measurements taken before and after instruction.

At the pre-test stage, pupils in the VRLE group recorded a mean mathematics achievement score of 13.21, with a standard deviation of 4.19, indicating moderate achievement levels with some variation among pupils. Pupils in the CTM group recorded a lower mean score of 11.47, accompanied by a slightly higher standard deviation of 4.79, suggesting comparable dispersion but lower average performance. The between-group mean difference of 1.74 shows that pupils in the VRLE group had a higher average mathematics achievement at the beginning of the study.

At the post-test stage, pupils exposed to the virtual reality learning environment recorded a mean achievement score of 20.22, with a reduced standard deviation of 3.46, reflecting improved performance and a more closely clustered distribution of scores. In comparison, pupils taught using the conventional teaching method recorded a mean achievement score of 18.27, with a higher standard deviation of 4.82, indicating improvement in achievement but with greater variability among pupils. The post-test between-group mean difference of 3.47 favours the VRLE group.

An examination of the mean gain scores further illustrates the effect of the instructional approaches. Pupils in the VRLE group recorded a mean gain of 8.53 in mathematics achievement scores from pre-test to post-test, while pupils in the CTM group recorded a mean gain of 6.80. The difference between the gain scores was 1.73, indicating a larger increase in mean mathematics achievement for pupils exposed to the virtual reality learning environment over the period of instruction.

Research question two

What is the difference in the mean mathematics achievement scores of male and female basic school pupils exposed to a virtual reality learning environment in Jalingo Education Zone?

Table 2

Mean and Standard Deviations of mathematics achievement Scores of Male and Female Basic School Pupils Exposed to a virtual reality learning environment in Jalingo Education Zone

Sex	**N**	**Pre-test**		**Post-test**		**Mean**
		$\overline{X}$	δ	$\overline{X}$	δ	**Diff**
Male	38	13.68	3.27	21.74	3.44	0.28
Female	66	12.94	4.65	20.22	3.46	0.45
Mean Difference		0.06		0.11		0.17

Table 2 presents the mean mathematics achievement scores and corresponding standard deviations of male and female basic school pupils exposed to a Virtual Reality Learning Environment (VRLE), measured at the pre-test and post-test stages.

At the pre-test stage, male pupils recorded a mean mathematics achievement score of 13.68, with a standard deviation of 3.27, indicating relatively clustered achievement levels among the male pupils prior to the intervention. Female pupils recorded a slightly lower mean score of 12.94, accompanied by a higher standard deviation of 4.65, suggesting greater variation in achievement levels within the female group at the beginning of the study. The between-group mean difference of 0.06 shows a marginal difference in favour of male pupils at pre-test.

At the post-test stage, male pupils recorded a higher mean mathematics achievement score of 21.74, with a standard deviation of 3.44, reflecting improved performance with moderate dispersion of scores. Female pupils also showed improvement, recording a mean score of 20.22, with a closely comparable standard deviation of 3.46, indicating a similar level of score consistency across the group. The between-group mean difference at post-test was 0.11, favouring the male pupils.

The mean gain scores shows that male pupils recorded a mean gain of 0.28 in mathematics achievement scores from pre-test to post-test, while female pupils recorded a

mean gain of 0.45. The difference between the gain scores was 0.17, indicating a slightly larger increase in mean achievement scores among female pupils over the period of exposure to the virtual reality learning environment.

Research question three

What is the interaction effect of learning environment (virtual reality versus conventional) and gender on the mean mathematics achievement scores of basic school pupils in Jalingo Education Zone?

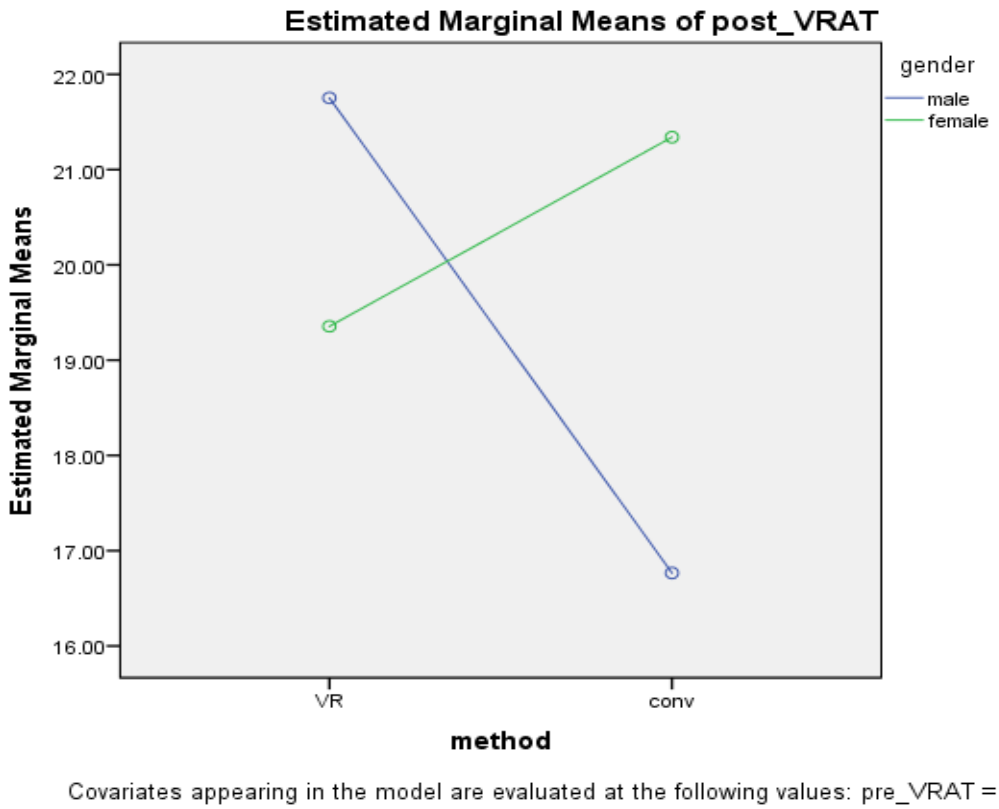

Figure 1. Plot showing the interaction effect of learning environment (virtual reality versus conventional) and gender on the mean mathematics achievement scores of basic school pupils in Jalingo Education Zone

The plot shows that pupils taught using the virtual reality learning environment recorded higher mean mathematics achievement scores than those taught using the conventional teaching
method, for both male and female pupils. However, the pattern of improvement differs by gender. The increase in mean achievement scores associated with the virtual reality learning environment is more pronounced for male pupils than for female pupils. Under the conventional teaching method, the difference in mean achievement scores between male and female pupils is relatively small.

The non-parallel nature of the lines representing male and female pupils across the two learning environments indicates an interaction effect, showing that the effect of the learning environment on pupils' mathematics achievement varies by gender.

Hypothesis one

There is no significant difference in the mean mathematics achievement scores of basic school pupils taught using a virtual reality learning environment and those taught using the conventional teaching method in Jalingo Education Zone.

Table 3

Results of one-way ANCOVA on mean mathematics achievement scores of basic school pupils taught using a virtual reality learning environment and those taught using the conventional teaching method in Jalingo Education Zone.

Sources of Variation	Sum of Squares	df	Mean Square	F	Sig	eta squared
Corrected Model	180.470[a]	2	90.235	5.263	0.006	0.053
Intercept	8254.067	1	8254.067	481.448	0.000	0.720
Pre VRAT	0.790	1	0.790	0.046	0.830	0.000
Method	177.595	1	177.595	10.359	.002	0.052
Error	3205.972	187	17.144			
Total	74430.000	190				
Corrected Total	3386.442	189				

a. R Squared = .053 (Adjusted R Squared = .043)

Table 3 presents the results of a one-way Analysis of Covariance (ANCOVA) conducted to examine the effect of instructional method on pupils' mean mathematics achievement scores, with pre-test mathematics achievement scores used as a covariate.

The result for instructional method shows a sum of squares of 177.595 with 1 degree of freedom, producing a mean square value of 177.595. This yielded an F-value of 10.359 with a corresponding significance value (p) of 0.002. Since the p-value is less than the 0.05 level of significance, instructional method has a statistically significant effect on pupils' mean mathematics achievement scores after controlling for pre-test achievement.

The eta squared (η^2) value of 0.052 indicates that approximately 5.2% of the variance in pupils' mathematics achievement scores is attributable to the instructional method, representing a moderate effect size in educational research contexts.

Based on this result, the null hypothesis stating that there is no significant difference in the mean mathematics achievement scores of pupils taught using a virtual reality learning environment and those taught using the conventional teaching method is rejected.

Hypothesis two

There is no significant difference in the mean mathematics achievement scores of male and female basic school pupils exposed to a virtual reality learning environment in Jalingo Education Zone

Table 4

Results of one-way ANCOVA on the mean mathematics achievement scores of male and female basic school pupils exposed to a virtual reality learning environment in Jalingo Education Zone

Sources of Variation	Sum of Squares	df	Mean Square	F	Sig	eta squared
Corrected Model	140.084[a]	2	70.042	6.467	0.002	0.114
Intercept	13288.004	1	13288.004	1226.963	0.000	0.924
Pre VRAT	2.524	1	2.524	0.233	0.630	0.002
Gender	136.566	1	136.566	12.610	0.001	0.111
Error	1093.830	101	10.830			
Total	43759.000	104				
Corrected Total	1233.913	103				

a. R Squared = .114 (Adjusted R Squared = .096)

The result for gender shows a sum of squares of 136.566 with 1 degree of freedom, yielding a mean square value of 136.566. This produced an F-value of 12.610 with a corresponding significance value (p) of 0.001. Since the p-value is less than the 0.05 level of significance, gender has a statistically significant effect on pupils' mean mathematics achievement scores after adjusting for pre-test achievement.

The eta squared (η^2) value of 0.111 indicates that approximately 11.1% of the variance in pupils' mathematics achievement scores is attributable to gender, reflecting a relatively large effect size in the context of educational research.

Based on this result, the null hypothesis stating that there is no significant difference in the mean mathematics achievement scores of male and female basic school pupils exposed to a virtual reality learning environment is rejected.

Hypothesis three

There is no significant interaction effect of learning environment (virtual reality versus conventional) and gender on the mean mathematics achievement scores of basic school pupils in Jalingo Education Zone

Table 4

Results of two-way ANCOVA for the interaction effect of learning environment (virtual reality versus conventional) and gender on the mean mathematics achievement scores of basic school pupils in mathematics in Jalingo Education Zone.

Sources	Type III Sum of Sq	df	Mean Square	F	Sig	Eta Sq
method	91.464	1	91.464	6.332	0.013	0.033
Gender	49.911	1	49.911	3.455	0.065	0.018
Method*gender	514.710	1	514.710	35.633	0.000	0.162

Table 4 presents the results of a two-way Analysis of Covariance (ANCOVA) conducted to examine the interaction effect of learning environment and gender on pupils' mean mathematics achievement scores, after controlling for pre-test achievement scores.

The result for the interaction between learning environment and gender (Method × Gender) shows a Type III sum of squares of 514.710 with 1 degree of freedom, yielding a mean square value of 514.710. This produced an F-value of 35.633 with a corresponding significance value (p) of 0.000. Since the p-value is less than the 0.05 level of significance, the interaction effect of learning environment and gender on pupils' mathematics achievement scores is statistically significant.

The eta squared (η^2) value of 0.162 indicates that approximately 16.2% of the variance in pupils' mathematics achievement scores is attributable to the interaction between learning environment and gender, representing a large interaction effect within the context of educational research.

Based on this result, the null hypothesis stating that there is no significant interaction effect of learning environment and gender on the mean mathematics achievement scores of basic school pupils is rejected.

Discussion of Findings

This section discusses the study's findings in relation to the research objectives, the theoretical frameworks underpinning the study, and the empirical literature reviewed. Rather than restating statistical results, the discussion interprets the patterns and meanings of the findings, with particular emphasis on pupils' interest in mathematics, mathematics achievement, and gender-related differences in virtual reality and conventional learning environments. By situating the findings within relevant learning theories and engaging critically with prior empirical studies, the discussion highlights areas of convergence, divergence, and contribution to knowledge, thereby deepening understanding of the pedagogical implications of virtual reality–based instruction for basic school mathematics.

Virtual Reality and Mathematics Achievement: Cognitive Depth and Knowledge Integration

The significant effect of instructional method on pupils' mathematics achievement can be further illuminated using the Cognitive Theory of Multimedia Learning, the Dual Coding Theory, and the Schema Theory. These frameworks posit that learning is enhanced when learners are exposed to multiple representational modes that support deeper cognitive processing and integration of new information into existing knowledge structures. Empirical studies reviewed in this study consistently reported superior achievement outcomes for learners exposed to virtual reality or game-based instructional approaches compared with conventional methods. For example, Udoh and Ekon (2018) found that students taught using virtual reality performed significantly better than those taught using traditional methods, while Akman and Çakır (2020) reported significant achievement gains among pupils exposed to virtual reality–based mathematics instruction. Similarly, Omeodu and Fredrick (2019) demonstrated that game-based instructional strategies enhanced students' mathematics achievement by promoting active problem-solving and sustained engagement.

The present study strengthens this body of evidence by demonstrating that these cognitive benefits are not limited to older learners or advanced mathematical topics but are also evident at the basic school level. This finding suggests that virtual reality can support foundational conceptual understanding, rather than merely enhancing surface-level performance.

Gender Differences in Mathematics Achievement

While virtual reality appeared to reduce gender differences in interest, the persistence of gender differences in mathematics achievement invites a more nuanced interpretation grounded in Self-Efficacy Theory and Social Cognitive Theory. Achievement

outcomes are closely linked to learners' beliefs about their capabilities, which are shaped over time by prior experiences, cultural expectations, and socialisation processes.

This interpretation helps reconcile the present findings with the mixed results reported in the empirical literature. Whereas Udoh and Ekon (2018) reported minimal gender differences in achievement outcomes, the current study suggests that gender-related disparities may persist even within innovative learning environments, depending on contextual and learner-specific factors. This highlights the importance of viewing technology-enhanced instruction as a supportive, rather than wholly transformative, influence on entrenched achievement patterns.

Interaction Effects

The statistically significant interaction effects of learning environment and gender on mathematics achievement represent one of the most theoretically rich outcomes of the study. These findings are consistent with Learner–Environment Interaction Theory, which posits that instructional effectiveness is shaped by the interplay between learner characteristics and learning contexts.

Rather than suggesting that virtual reality has a uniform effect on all learners, the interaction effects indicate differential responsiveness, with the impact of virtual reality instruction varying across gender groups. This finding diverges from the results reported by Ityavzua (2019), who found no significant interaction effect of instructional method and gender on students' interest. However, it aligns with the position advanced by Garduño et al. (2021), who emphasised the need to examine moderating variables in immersive learning environments. The present study therefore extends the existing empirical literature by demonstrating that gender moderates the effectiveness of virtual reality instruction in basic school mathematics.

Conclusion

Based on the findings of the study, the researcher drew the following conclusions.

1) The use of Virtual Reality Learning Environment (VRLE) results in students' higher achievement than the use of Conventional Teaching Method (CTM). Instructional method had a statistically significant effect on pupils' achievement after controlling for pre-test scores
2) Gender is a significant factor affecting students' achievement in Mathematics when taught under Virtual Reality Learning Environment (VRLE).
3) A statistically significant interaction effect of learning environment and gender was also found on pupils' mathematics achievement scores, suggesting that the influence of virtual reality instruction on achievement differed for male and female pupils.

Recommendations

The following recommendations have been made based on the findings of this study. Mathematics teachers should endeavor to develop and adopt Virtual Reality Learning Environment as it would enhance overall interest and achievement in science as well as help reduce gender gap in Mathematics.

Regular sensitization workshops should be organized by the Universal basic education commission to retrain Mathematics teachers on the development and use of Virtual Reality Learning Environment.

Pre- service teachers should be trained on how to develop and employ the use of Virtual Reality Learning Environment

Government, in conjunction with other professional bodies, should sponsor further research on the use of Virtual Reality Learning.

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