

Effect of 3d Interactive Virtual Laboratory Computer-Simulated Experiments on Male and Female Senior Secondary School Students' Achievement and Retention in Chemistry

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Abstract

This study investigated the effect of 3D Interactive Virtual Laboratory computer-simulated experiments on male and female senior secondary school students' achievement and retention in Chemistry Subject. The study adopted a quasi-experimental design in which intact classes were used. It was guided by two research questions and two null hypotheses. The population comprised 234 SS II Chemistry students from Anambra East Local Government Area of Anambra State, Nigeria. The sample consisted of 71 SS II Chemistry students drawn from four co-educational schools using a simple random sampling technique (balloting without replacement). Data were collected using a Chemistry Achievement Test (CAT) titled 3D Interactive Virtual Laboratory Achievement Test (3D IVLAT). The instrument was validated by two experts in Chemistry Education and one expert in Measurement and Evaluation. Its reliability was established using Spearman Rank Order, yielding a coefficient of 0.81. The data collected were analyzed using mean, standard deviation, and t-test. Mean and standard deviation were employed to answer the research questions, while t-test was used to test the hypotheses at a 0.05 level of significance. The findings revealed that female students taught Chemistry with the 3D Interactive Virtual Laboratory had higher mean achievement and retention scores than male students taught with the 3D Interactive Virtual Laboratory. Furthermore, there was no significant difference in the mean achievement and retention scores of male and female students taught Chemistry with the 3D Interactive Virtual Laboratory. Based on these findings, appropriate recommendations and conclusions were drawn.

Keywords: Interactive Virtual Laborator, Achievement, Chemistry, Computer Simulated Experiments, Gender and Retention

Introduction

Education is a complex concept that is difficult to define because of the many functions it performs in society. Etymologically the word *education* is commonly traced to the Latin terms *educare* ("to bring up" or "to rear") and *educere* ("to lead out" or "to bring forth"), suggesting the development and cultivation of a person's abilities. Scholars have described education in various ways. United Nations Educational, Scientific and Cultural Organization (UNESCO (2021)) views education as a social institution shaped to address the changing needs and expectations of society. Birabil & Ogeh, (2020) views it as preparation for individuals to live and function in society. Njoku and Nwokah (2018) describe education as the process of developing an individual's innate abilities and competencies for effective living. UNESCO (2021) explains that education equips individuals with the knowledge, skills, values and attitudes needed for productive participation in society. Abolarin (2019) views education as a process through which individuals acquire knowledge, skills, and values for effective personal and societal development.

Science, closely linked to education, plays an important role in technological advancement and industrial development. According to Klimuk, Tarasova, Yulia, & Laura (2020), science and education are essential drivers of technological advancement and industrial development. It underpins

improvements in quality of life, sustainable development and peaceful coexistence (UNESCO, 2021). From basic needs such as food, water and shelter to fields like agriculture, health and communication, science provides the foundation for action at all levels of society. UNESCO (2021) and United Nations Conference on Trade and Development (UNCTAD (2023)) recognize science and technology as major drivers of economic growth, social transformation and industrialization. Science is an organized body of knowledge expressed through concepts, laws, theories and generalizations.

The practical application of science through technology has made science education a priority in developed nations, where funding research is seen as a long-term investment. UNESCO (2021) noted that economic productivity and national development are strongly linked to scientific education and the training of skilled human resources.

Chemistry is the science that studies matter, energy, and their interactions, including the transformation of substances for human and industrial purposes (Brown, LeMay, Bursten, Murphy, Woodward, & Stoltzfus 2018). Chemistry comprises major branches such as organic, inorganic, physical, and analytical chemistry, with related fields like biochemistry and geochemistry (American Chemical Society, 2022). In Nigeria, Chemistry is a core senior secondary school subject that supports technological growth and prepares students for careers in engineering, medicine, pharmacy and other science-related fields (Omiko, 2015). Brown et al. (2018) describe chemistry as the central science because it connects physics with biology and supports many aspects of modern daily life. Chemistry is a practical and experimental science that requires hands-on laboratory activities and empirical reasoning for effective learning and application. (Taber, 2019).

A simulation is a model that imitates the operation of a real or proposed system, allowing users to test scenarios, predict outcomes and improve decision-making. When combined with virtual reality, it can provide immersive experiences for training, safety, performance optimization, theory testing and entertainment. Computer simulation involves the use of mathematical, logical, or statistical models on computers to imitate the behavior of real-world systems or processes. (Law, 2019).

Virtual laboratories enhance teacher–student interaction, reduce instructional costs, and provide safe and flexible access to practical learning experiences (Makransky, Thisgaard, & Gadegaard, 2016; Aljuhani, Sonbul, Althabiti, & Meccawy, 2018). They can be delivered via web platforms or CDs, often supported by discussion forums, videos, glossaries and email communication, applicable across disciplines like Physics, Chemistry, Biology, earth sciences and software engineering. Virtual laboratories help students test ideas, observe reactions and acquire results in a simulated setting.

3D animation is the process of creating moving three-dimensional images in a digital context. These visuals are made using 3D software, allowing animators to create computerized objects that look 3D even though they're on a 2D surface. Through visual effects and precise timing, animators can make anything from a video game character to a car in an advertisement look like it's moving through a three-dimensional space.

Academic achievement refers to the knowledge, skills, and level of attainment a learner demonstrates through progress checks, examinations and mastery of school subjects. It is commonly measured by grades, test performance or the extent to which educational goals are met (Parveen, Syed, & Syed, Nazir, 2013). Scholars describe it as the outcome of educational experiences, reflecting a student's ability to learn, apply skills, overcome challenges, and accomplish tasks requiring effort and proficiency (Ambrose, Bridges, DiPietro, Lovett, & Norman, 2018; Anderson, 2020; Woolfolk, 2019). Therefore this study investigated the effect of 3D Interactive Virtual Laboratory computer-

simulated experiments on male and female senior secondary school students' achievement and retention in Chemistry Subject.

Academic achievement reflects the process and outcomes of learning, showing learners' progress toward curriculum objectives and levels of educational success (Woolfolk, 2019). Retention is the ability to store learned information and later retrieve it from short-term or long-term memory (Anderson, 2020). Woolfolk (2019) defines retention as the ability to store information and recall it when needed from memory systems. It involves encoding, storage and retrieval of knowledge so it can be remembered and applied in the future (Parveen et al., 2013). Retention is an important indicator of learning and cognitive ability and is often measured through delayed tests administered days or weeks after instruction to determine how much information learners can still recall (Ambrose et al., 2018; Woolfolk, 2019). Gender refers to the socially and culturally constructed roles, behaviours, and expectations associated with males and females, whereas sex refers to biological differences between them (World Health Organization (WHO), 2022; United Nations Children's Fund (UNICEF), 2021). Societal stereotypes often portray men as bold, intelligent and assertive and women as passive or submissive, but these traits are not innate and do not determine academic achievement (Okeke, 2018). However, factors such as sex-role stereotyping, socialization processes, masculine images in science textbooks and teacher attitudes can influence the performance of male and female students in subjects like Chemistry (Oriola & Owoseni, 2024). This study investigated the effect of 3D Interactive Virtual Laboratory computer-simulated experiments on male and female senior secondary school students' achievement and retention in Chemistry Subject.

Statement of the Problem

Nigeria's persistent poor performance in Chemistry remains a major concern. West African Examination Council (WAEC) reports and Chief Examiners' findings consistently show declining achievement, with many students struggling with key concepts and problem-solving. WAEC reported that students show persistent weaknesses in mole calculations, gas laws, balancing equations, and other quantitative chemistry concepts. Although recommendations have been made, they largely point to ineffective teaching methods and inadequate practical exposure as the main causes. WAEC noted that inadequate laboratory facilities and limited instructional resources contribute to students' difficulties in practical Chemistry. As a result, students miss meaningful hands-on experiences. The use of virtual laboratories and computer-simulated experiments should be recommended for science teaching, although their adoption in many Nigerian schools remains limited. This creates a gap in understanding their effect on students' achievement and retention in Chemistry, and the present study aims to fill that gap.

Purpose of the Study

The general purpose of the study was to investigate the effect of computer simulated experiments using 3D interactive Virtual Laboratory on senior secondary school students' achievement and retention in Chemistry. Specifically, the study sought to:

1. Determine the mean achievement scores of male and female students taught Chemistry using 3D interactive virtual laboratory.
2. Ascertain the mean retention scores of male and female students taught Chemistry using 3D interactive virtual laboratory.

Research Questions

The following research questions guided the study:

1. What are mean achievement scores of male and female students taught Chemistry using 3D interactive virtual laboratory?
2. What are the mean retention scores of male and female students taught Chemistry using 3D interactive virtual laboratory?

Research Hypotheses

The following null hypotheses which were tested at .05 level of significance provided focus to this study.

1. There is no significant difference in the mean achievement scores of male and female students taught Chemistry using 3D interactive virtual laboratory.
2. There is no significant difference in the mean retention scores of male and female students taught Chemistry using 3D interactive virtual laboratory.

Method

The study adopted a quasi-experimental research design, which employed intact classes because the design does not allow for the random assignment of subjects to experimental and control groups. This aligns with Creswell and Creswell (2018) who explained that quasi-experimental research often uses intact groups because random assignment may not be feasible in educational settings. The population of the study comprised 234 Senior Secondary II Chemistry students in secondary schools in Anambra East Local Government Area of Anambra State, Nigeria. From this population, a sample of 71 students was drawn from two co-educational secondary schools selected out of the ten schools in the area using a simple random sampling technique. The two sampled schools were the treatment groups. The instrument for data collection was the Chemistry Achievement Test (CAT), titled 3D Interactive Virtual Laboratory Achievement Test (3D IVLAT). The test consisted of 20 objective questions on chemical reactions, with each question carrying five marks. The instrument was divided into two sections: Section A collected students' biodata, while Section B contained the objective test items. The 3D IVLAT was used to measure both achievement and retention. To ensure validity, the instrument was reviewed by two experts in Chemistry Education and one expert in Measurement and Evaluation. Its reliability was established using the Spearman Rank Order Correlation Coefficient, yielding an overall reliability coefficient of 0.81, which was considered satisfactory for the study. The experimental procedure was carried out in two phases. The first phase involved the training of research assistants, who were the students' regular Chemistry teachers. They received three days of training from the researchers on how to implement the lesson plans. The second phase involved teaching the students and administering the 3D IVLAT. Both schools were given a pre-test before instruction. The teaching lasted four weeks, after which the test items were rearranged and administered as a post-test. Two weeks later, the same instrument, rearranged again, was given as a retention test. In total, the entire teaching and data collection lasted six weeks. Normal intact classes were maintained, and no alterations were made to the school timetable. For data analysis, mean and standard deviation were used to answer the research questions, while a t-test was employed to test the null hypotheses at the 0.05 level of significance.

Results

Research Question 1

What are the mean achievement scores of male and female students taught Chemistry using 3D interactive virtual laboratory?

Table 1: Mean and Standard Deviation Scores on Students' Pre-test and Post-test Achievement by Exposure to 3D IVL and Gender

Gender	Pre-test			Post-test		Mean Difference
	N	Mean	Standard Deviation	Mean	Standard Deviation	
Male	37	25.27	9.50	74.19	9.54	48.92
Female	34	24.12	9.49	73.68	13.10	49.56
Mean Difference		1.15		0.51		0.64

Mean scores displayed in Table 1, showed that the pre-test and post-test Chemistry

achievement scores of male students taught with 3D IVL were 25.27 and 74.19 while the means scores of the female students taught with the same teaching method were 24.12 and 73.68. The standard deviation scores were 9.50 and 9.54 for the males, and 9.49 and 13.10 for the females. These mean differences implies that female students were slightly better than male students in Chemistry achievement as shown by the 0.64 differences in favour of females.

Research Question 2

What are the mean retention scores of male and female students taught Chemistry using 3D interactive virtual laboratory?

Table 2: Mean and Standard Deviation Scores on Students' Chemistry Retention by Exposure to 3D IVL and Gender

Gender	N	Post test	Standard Deviation	Retention test	Standard Deviation	Mean Difference
Male	37	74.19	9.54	76.22	9.68	0.84
Female	34	73.68	13.10	77.06	12.25	

As shown in Table 2 above, the mean retention in Chemistry for male students taught with 3D IVL was 76.22 while the mean retention in Chemistry for the female students was 77.06. The standard deviation scores for male and female were 9.68 and 12.25 respectively. The mean difference of 0.84 in favour of female students suggests that female students had slightly greater retention score than the male students.

Hypothesis 1

There is no significant difference in the mean achievement scores of male and female students taught with Chemistry using 3D interactive virtual laboratory.

Table 3: Independent Samples t-test Analysis on Post-test Mean Achievement Scores of Students to 3D IVL and Gender

Gender	Post-test		df	t_{cal}	p -value	Remark
	Mean	Standard Deviation				
Male (n = 37)	74.19	9.54	69	0.19	0.850	NS
Female (n=34)	73.68	13.10				

The independent samples t-tests results displayed in Table 3 shows the mean difference between male and female students taught with 3D IVL was statistically non-significant, $t(69) = 0.19$, $p=0.850$. Since the p -value was greater than 0.05 level of significance, the null hypothesis was not rejected.

Hypothesis 2

There is no significant difference in the mean retention scores of male and female students taught Chemistry using 3D interactive virtual laboratory.

Table 4: Independent Samples t-test Analysis on Mean Retention Scores of Students to 3D IVL and Gender

Gender	Post-test		df	t_{cal}	p -value	Remark
	Mean	Standard Deviation				
Male (n = 37)	76.22	9.68	69	-0.32	0.748	NS
Female (n=34)	77.06	12.25				

The independent samples t-tests results displayed in Table 4 above shows the mean difference between male and female students taught with 3D IVL was statistically non-significant, $t(69) = -0.32$, $p=0.748$. Since the p -value was greater than 0.05 level of significance, the null hypothesis was not rejected.

Discussion

The effect of 3D interactive virtual laboratory on male and female students' achievement in Chemistry

Research question one revealed that female students taught with 3D interactive virtual laboratory were slightly better than male students in chemistry achievement. This is not in agreement with the view of Afolabi and Akinbobola (2020) who opined that there was no significant difference in the achievement scores of male and female students exposed to computer-assisted Chemistry instruction. In addition to that, Okwuduba, Offiah, & Madichie, (2018) stated that there was no significant difference on students' achievement due to gender.

Hypothesis one revealed that there is no significant difference in the mean achievement scores of male and female students taught with Chemistry using 3D interactive virtual laboratory. This is in line with the view of Ogunkunle and Akinsola (2020) who opined that gender had no significant effect on achievement of students taught Chemistry using 3D interactive virtual laboratory.

The effect of 3D interactive virtual laboratory on male and female students' retention in Chemistry.

Research question two revealed that female students taught with 3D interactive virtual laboratory had slightly greater retention score than the male students. This is not line with the view of Okwuduba *et al*, (2018) who opined that there was no significant difference on students' content retention due to gender. In addition to that, Ogunkunle and Akinsola (2020) stated that gender had no significant effects on students' content retention.

Hypothesis two revealed that there is no significant difference in the mean retention scores of male and female students taught Chemistry using 3D interactive virtual laboratory. This is in line with the view of Okwuduba *et al*, (2018) who opined that there was no significant difference on student's content retention based on gender.

Conclusion

The study in its findings and discussions concluded that there is no significant difference in the mean achievement scores of male and female students taught Chemistry using 3D interactive virtual laboratory. In addition to that, there is no significant difference in the mean retention scores of male and female students taught Chemistry using 3D interactive virtual laboratory.

Recommendations

Based on the findings the following recommendations are made:

- ❖ **School administrators** should provide functional computer laboratories and ensure steady power supply to enable effective use of interactive virtual laboratory packages during Chemistry lessons.
- ❖ **Government and policy makers** should allocate adequate funds for the procurement of digital devices, internet facilities, and maintenance of ICT infrastructures needed for virtual laboratory instruction.

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