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Effects of Virtual and Augmented Reality Teaching Strategies on Students' Understanding of Chemistry Practical Activities

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Abstract
The study investigated the effect of virtual reality (VR) and augmented (AR) teaching strategies on students' understanding of chemistry practical. Two research questions and hypotheses guided the study. The population of the study comprised all Chemistry students in public secondary schools in Calabar Municipality. The sample of the study was made up of 100 chemistry students from 4 public secondary schools. The design used was pretest, posttest, non-randomized, non-equivalent design involving the two experimental and one control group. The instrument of the study was a validated Chemistry Achievement Test (CAT) based on practical chemistry taught to both groups using (VR) and (AR) which consisted 30 multiple choice questions drawn from standardized past SSCE questions. Reliability of the instrument was ascertained using Kudar-Richardson formular (KR-20). The experimental classes were taught chemistry practical using VR and AR instructional strategies for six weeks while the control group was taught without VR and AR teaching strategies rather employed the use of conventional method. The students were pretested before the commencement of the treatment and a posttest was also administered after the treatment. Data obtained was analyzed using analysis of covariance (ANCOVA) at 0.05 level of significance. Result of data analysis showed variance of students taught with VR and AR recorded higher achievement scores compared with those taught without VR and AR in chemistry. It was concluded that the use of VR and AR significantly contribute to the variance in students' academic achievement in Chemistry. It was recommended among others that the use of VR and AR realities in teaching chemistry practical serves as a catalyst to promoting students' understanding of chemistry in public secondary school. Hence, Chemistry teachers should adopt new technologies as VR and AR instructional strategies to encourage students' participation and achievement in Chemistry.

Keywords: Virtual Reality, Augmented Reality, Strategies, Chemistry, Students'

Introduction

The importance and value of science education in any developing nation cannot be over-emphasized. The knowledge, skills and materials used the economic development are derived from science and technology. Teaching and learning are like two sides of a coin. They are mutually complementary that one cannot do without the other. Teaching and learning tasks and activities are organized in such a manner that learners interact actively with the resources or environment for efficient and effective changes to take place in the learner. Yilmaz (2023) noted that the experiences make for learning participatory by students under the guidance of the teachers. This is because what they gather make the learning task to be relevant to their needs and aspirations. The more the tasks are relevant to the needs of the learners, the more the motivation and interest in mastering the contents and skills.

Most students have phobia in Chemistry due to its content and abstract nature and language of interactions that demands balancing of equations and calculations. To reduce the complexity of the subject, a lot of emphasis has been placed on the method of presentation of content to enable students assimilate and promote their academic achievement and retention. But despite the number of efforts and emphasis, science teachers (including chemistry teachers) in Nigerian schools still revert to use of expository or "chalk and talk" method of teaching which had been the traditional approach of instruction rather than interactive and investigate approaches (Amugwo, 2015).

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Secondary school student's knowledge of science is often characterized by lack of coherence and the majority of student engage in essentially rote learning.

Chemistry has witnessed a deplorable trend in recent years compared to any other science subject in the final year external examination (Kim, 2021) noted that there has not been corresponding increase in students' academic achievement and in spite of the efforts of both Federal and State governments to encourage chemistry education, students' failure in chemistry in Senior Secondary school Certificate Examination (SSCE) is high (Chen & Lin 2020). One of the major reasons for this poor performance could be attributed to ineffective methods of chemistry instruction adopted by Nigerian Secondary School teachers. Yildrum et al. ((2021) reported that teachers shy away from the more effective activity-oriented teaching methods that promote students centered interactions in the classroom. The 21st century industrialization drive has highlighted the need for embracing the integration of modern technologies in many sectors of the society, which education sector is not an exception. This has resulted in the deployment of educational technology in the teaching and learning of chemistry with the aim of promoting a fascinating educational experience and enhancing students' practical engagement and academic achievement at all levels of education. Yilmaz (2023) reported that the incorporation of technologies into lessons enables the teachers create more engaging and interactive learning experiences for students by providing tools to facilitate the exploration and understanding of scientific concepts thereby promoting critical thinking, problem-solving skills, and collaboration. The application of new technologies in science education to facilitate better understanding has necessitated a paradigm shift from the conventional approach of teaching and learning to an advanced digital mode of teaching and learning chemistry. Virtual reality (AR) and augmented reality (AR) technologies have been of great importance to teachers and students as students learn science with much fun through hands-on experience, particularly in chemistry where it is proven to be one of the technology assisted instructional learning that encourage effective interactive tools for students to experience varieties of learning in practical reality.

Virtual and augmented realities introduces students to immersive digital experiences that cannot be reproduced using traditional teaching method (Phakamach et al., 2022. These technologies enable students to interact better with complex material (Sun et al., 2022). While providing enabling environment for teachers to customize content based on individual learning styles (Childs et al., 2021). Besides, these technologies does not only create a more immersive experience, but equally offer the potential for educators to provide simulations and step-by-step virtual field trips without the physical travel implications (Chin, Delaegher & Chao 2023). Science education is currently experiencing a breakthrough in the use of innovative instructional strategies to enhance better learning outcomes in science subjects, particularly chemistry.

Chemistry teaching and learning has been an atmosphere for the exhibition of various practices an learning experiences where students engage in virtual or realia interactions and other simulations with virtual and augmented objects. However, with the use of VR and AR into chemistry teaching, students and teachers find chemistry practical safe and interesting enough to learn and this offers a wide range of opportunities for students to develop their science skills and equally improve upon their learning outcome in chemistry. From the foregoing, chemistry teachers and students would find AR and VR to be of tremendous help by engaging them not only in theoretical concepts but also in complex practical which takes place in the laboratory. Virtual reality (VR) and augmented reality (AR) enables teachers and students experience teaching and learning in a more comprehensive and realia way. This paper, therefore, seeks to find out if the use of:

Virtual reality is a technology that creates a stimulated environment that learners can interact with in real time. It uses three dimensional images or environment that can be interaected with in a seemingly real or physical way by a person using special electronic equipment such as a helmet with screen inside or gloves fitted with sensors. Virtual reality can also be defined as a simulated experience that employs 3D near-eye displays and pose tracking to give the user an immersive feel of a virtual world. It is a computer modeling and simulation that enables a person to interact with artificial three-dimensional special goggles headsets place over the eyes and fully immerse the user in a virtual environment, creating a realistic experience in the simulation.

The use of virtual reality (VR) and augmented reality (AR) in teaching chemistry is becoming increasingly overwhelming, as safety measures and other prerequisite knowledge and skills required for effective laboratory experiments and handling of laboratory equipment through can be carried out using these technologies. Yıldırım et al. (2020) reported that virtual reality increases students' interest and motivation to learn. Chien et al. (2020) shared the same view when they stated that the virtual reality environment increase motivation and critical thinking skills and decreased anxiety. Akgun and Atici (2022) reported that immersive virtual reality had many positive effects on students' cognitive, affective, and psychomotor skills that created a perception of reality and

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sense of presence in students, facilitates learning, increases motivation, creates a safe and interactive learning environment and make many contributions to learning. Before the adoption of these technologies in the teaching of sciences, most experiments were conducted taking into consideration the high risk factor, volatility and explosive nature of most chemicals in the science laboratory, especially those of chemistry. Such chemicals can inflict injuries on chemistry teachers and students when adequate precautionary measures are not take into consideration, hence projecting the subject to be scary one to both teachers and students thereby preventing students from having a critical observation of the reaction of substances and their interaction with other substances. However, with the use of VR and AR into chemistry teaching, students and teachers find chemistry practical safe and interesting enough to learn and this offers a wide range of opportunities for students to develop their science skills and equally improve upon their learning outcome in chemistry. From the foregoing, chemistry teachers and students would find AR and VR to be of tremendous help by engaging them not only in theoretical concepts but also in complex practical which takes place in the laboratory. Virtual reality (VR) and augmented reality (AR) enables teachers and students experience teaching and learning in a more comprehensive and realia way. This paper, therefore, seeks to find out if the use of: Virtual reality and conventional method of teaching affect students' practical. The importance and value of science education in any developing nation cannot be over-emphasized. The knowledge, skills and materials used the economic development are panacea from science and technology. Teaching and learning are like two sides of a coin. They are mutually complementary that one cannot do without the other. Teaching and learning tasks and activities are organized in such a manner that learners interact actively with the resources or environment for efficient and effective changes to take place in the learner. Famuwagun (2019) defined Practical activities as any type of science teaching and learning activities in which students' working either individually or in small group are involved in manipulating and observing real object and materials. Practical activities help students to develop the scientific skills, enhance the learning of scientific knowledge; give insight to scientific method, stimulates students' interest; increase motivation to study science and develop scientific attitude, such as open-mindedness, objectivity among others.

Cetin-Dindar et al. (2018) posits that, the advent of technology has profoundly impacted the field of chemistry education. Furthermore, Ali and Ullah, (2020), opined that, from enhancing experimental accuracy to facilitating comprehensive understanding of complex concepts, technology's integration into education has been pivotal. Alqadri (2018) investigated that experiment-based learning is a quite effective learning method to study chemistry. The Integration of technology in education has witnessed a transformative shift, and one notable facet of this evolution is the incorporation of Augmented Reality (AR) into the instructional landscape. Augmented Reality (AR) combines the real world with virtual objects so that the virtual objects coexist in the same space as the real world (Azuma, 2021). AR differs from Virtual Reality (VR) in that AR devices overlay digital content onto the physical world. In contrast, VR devices are entirely closed off from the physical world, presenting a synthetic 3D virtual world (Wang et al., 2018). According to Azuma (2021), AR has three characteristics: it combines real and virtual objects in a real environment, runs interactively in real-time, and registers real and virtual objects with each other.

Augmented reality technology has been used in assembly (Curtis et al 2018). Medical applications (Barsom et al, 2016). Entertainment (Arino et al., 2022). And educational settings (Frank & Kapila, 2017). The use of AR in education environments is supported by the psychological theory known as constructivism, which states that learning is an active process for students to construct new knowledge based on previous knowledge. A learning environment based on the principles of the constructivist theory is bound to be interactive and dynamic, allowing students to modify the elements in their environment to try ideas and implement experiments (Dunleavy & Dede, 2022). AR allows the creation of such learning environments since it creates the opportunity for students to be active in the process (Yilmaz & Goktas, 2017) and to experiment with the material to be learned through learning-by-doing, which can be more effective to allow the understanding and retention of the material when compared with traditional teaching methods (Yang, 2022). The use of AR in the learning context can have a positive emotional impact on students, so it improves their cognitive processes and academic performance (Ibáñez et al, 2020). Additionally, it increments their attention, motivation, and satisfaction (Chang & Hwang, 2018). Another benefit of the use of AR in education is that it allows the creation of scenarios that are difficult to be available in real life (Wojciechowski & Cellary, 2023). It allows students to stay in control of the virtual environment which can increase their self-confidence and self-efficacy.

Several studies by Cardellini (2022), and Woldeamanuel et al. (2019), noted that many students have difficulties in understanding abstract concepts in chemistry. Some reasons for that could be due to the use of traditional approach and lack of hands-on activities during interaction. Academic achievement therefore is the act of gaining

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knowledge, the quality and quantity of a student's work that their gain. Based on that definition, achievement can also be defined as a success in achieving something desired. This study investigated the effect of virtual and augmented realities on students' understanding of chemistry practical. By exploring how these strategies align with established educational objectives and impact students' grasp of fundamental chemical concepts, the research aims to provide insights that can inform pedagogical practices and curriculum development.

Aim and Objectives of the Study

The aim of the study was to investigate effects of virtual and augmented reality teaching strategies on students' understanding of chemistry practical activities. The objectives were to find out if:

i. Virtual reality and conventional method of teaching affect students' practical understanding t in chemistry
ii. Augmented reality and conventional method affect students' practical understanding in chemistry

Research Questions

The following research questions were asked to guide the study

i. What is the mean score difference between the understanding of students taught chemistry through virtual reality (VR) and those taught with the conventional teaching method in chemistry?
ii. What is the mean score difference between the understanding of students taught chemistry using augmented reality (AR) and those taught through conventional teaching method in chemistry?

Hypotheses

The following research hypotheses were formulated for the study and tested at 0.05 level of significance

i. There is no significant effect of virtual reality on students' understanding of practical chemistry
ii. There is no significant effect of augmented reality on students' understanding of practical chemistry

Methods and Materials

The research design is pretest, posttest control non-equivalent quasi-experimental design. The experimental and control groups were taught chemistry practical with virtual and augmented reality while the control group was taught with conventional method. Before the treatment a pretest was administered to both experimental and control respondents, after which a treatment was carried out for a period of three weeks with the help of research assistants who were part of the research administration process. After the treatment procedure, a posttest was given to the both groups. Data obtained from the test was analyzed using analysis of covariance at 0.05 level of significance.

Results

Research Question 1:

Table 1: Mean (X) and standard deviation (SD) of students' pre-test and post-test scores classified by treatment groups.

Treatment Groups	N	Pre-test		Post-test		Mean Score	Gain
		□	SD	□	SD		
Control	60	16.23	5.97	38.13	4.77	21.90	
Experimental	40	16.57	4.34	41.67	2.81	25.10	

Table 1, shows the pre-test and post-test mean scores and standard deviation of scores of the of students taught using virtual reality (VR) and conventional strategies. The post-test - pre-test mean gain scores of 25.10 and 21.90 respectively, for those in Students VR and conventional strategy group show students in VR group had a slightly better mean gain score difference compared with those in Students conventional group. However, the post-test standard deviation scores of 2, 81 and 4.77 for students in VR and AR and conventional groups indicate that, though students taught using VR had the widest scattering of raw scores about the group mean, and a better mean gain score, those taught using conventional strategy had a closer scattering of raw scores about the group mean. Whether the observed differences in the mean scores of the two groups were statistically significant is assessed by the results for testing of hypothesis one displayed in Table 1.

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Hypothesis One:

Table 2: Summary of Analysis of Covariance (ANCOVA) of the students' post-test scores classified by treatment groups with pre-test scores as covariate taught with Virtual Reality and conventional methods in chemistry.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Decision at p<.05 alpha
Corrected Model	571.123[a]	3	190.374	13.228	.000	S
Intercept	11203.462	1	11203.462	778.453	.000	S
Pretest	9.673	1	9.673	.672	.414	S
Treatment * pre-test	159.988	1	159.988	11.116	.001	S
Error	1381.627	96	14.392			
Total	158373.000	100				
Corrected Total	1952.750	99				

a. R Squared = .292 (Adjusted R Squared =.270)

b. Computed using alpha = .05

In Table 2, the calculated F-ratio for the effect of instructional strategies at df 1, 99 is 11.11, while its corresponding calculated level of significance is .001 alpha. This level of significance is less than .05 in which the decision is based; indicating that there was a significant difference between the academic achievement of students taught using virtual reality and Conventional strategies. With this observation, null hypothesis 1 was rejected. The post-test mean scores and the mean gain show that the significance was in favour of students taught using VR with a higher mean score of 41.67 and a mean gain of 21.50 when compared with those in the conventional group.

Research Question Two:

Table 3: Mean and standard deviation of students' pre-test and post-test scores classified by treatment groups based on augmented reality in chemistry.

	N	N	Pre-test		Post-test		Mean Score	Gain
			□	SD	□	SD		
Experimental	50		18.60	5.37	39.76	4.14	23.76	
Control	50		12.18	3.44	21.48	2.75	18.28	

Table 3, shows the pre-test and post-test mean scores; and standard deviation of scores of the students taught using augmented and conventional strategies. The post reality t-test - mean gain of students in both groups are 39.76 and 21.48, respectively, while the mean gain score of male and female students in both groups are 23.76 and 23.06, respectively. These observations show that students taught using augmented reality benefited from the instructions given since the post-test scores in both groups is higher than the pre-test score but it was observed that the students taught with augmented reality had a higher mean gain score than the those taught with conventional method in chemistry. Whether the differences between the students in the two groups were statistically significant is assessed by the results in Table 4.6 used in the testing hypothesis three.

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Hypothesis Two:

Table 4: Summary of Analysis of Covariance (ANCOVA) of students taught with augmented reality and conventional method post-test scores classified by treatment groups with pre-test scores as covariate.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Decision at p<.05 alpha
Corrected Model	131.246[a]	3	43.749	2.307	.082	NS
Intercept	12414.450	1	12414.450	654.661	.000	S
Pre-test	124.328	1	124.328	6.556	.012	S
Control group	1.451	1	1.451	.077	.783	NS
Treatment	.327	1	.327	.017	.016	S
Error	1801.501	95	18.963			
Total	156437.000	99				
Corrected Total	1932.747	98				

a. R Squared =.068 (Adjusted R Squared = .038)
b. Computed using alpha = .05

In Table 4, the calculated F-ratio for the main effect of instructional strategies on male and female students' achievement when taught using AR and Conventional strategies at df 1, 99 is .077, while its corresponding calculated level of significance is .896 alpha. This level of significance is greater than .05 in which the decision is based; indicating that there was no significant difference between the academic achievement of students in the concepts taught given the instructional strategies used AR. With this observation, null hypothesis 2 was rejected and the alternate hypothesis. Therefore, there is a significant difference in the understanding of students taught with augmented reality and conventional method in chemistry.

Discussion

In this section the findings from the results in Tables are discussed in the order of the research questions/hypotheses.

Virtual Reality (VR) and Conventional Strategies and Students' Understanding of chemistry practical

The findings as regard the effect VR, and conventional strategies on students' understanding showed that there was a significant difference in the students' understanding of chemistry concepts was in favour of students taught using VR method. The effect of VR in the learning context can have a positive impact on students, hence it improves their cognitive processes. Additionally, it increases their attention, motivation, and satisfaction. Allowing, the creation of scenarios that are difficult to be available in real life and it also allows students to stay in control of the virtual environment which can increase their self-confidence and self-efficacy. This result is in agreement with the findings of Ibáñez et al. (2020), Yildirim et al. (2021), Wojciechowski and Cellary (2023), Arici and Simsek (2023), Monica et al. (2023), Hoai et al. (2024), and Cheng et al. (2024) this could be attributed to its ability to helps learners focus their energy on a task and its inter- and intrapersonal components that allow students to process information, move and interact with the learning material to gain the knowledge are targeted for learning outcome.

Augmented reality and conventional method on Student's understanding of chemistry practical

On the effect of augmented reality and conventional method on students' understanding of chemistry practicals. it was observed that its effect was statistically significant given the instructional strategies used. This observation indicates that augmented reality is a strong determinant of students' achievement of chemistry. This study is in line with those of Udousoro (2016), Hazir et al. (2020), and Oladejo et al. (2023), who also reported a significant effect of augmented reality on students' academic achievement. However, the finding contradicts that of

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Demircioglu et al. (2019), and Eya et al. (2020), who reported no significant difference in achievement between studnets' academic achievement taught with augmented reality in chemistry..

Conclusion

Based on findings of this study, it was concluded that there is a significant effect of virtual relality and augmented reality on students' understanding of practical Chemistry.

Recommendations

The researcher recommended that:

1. Chemistry teachers should be creative and innovative on the use of virtual and augmented realities as immersive technologies to improve students' understanding and academic achievement of chemistry concepts.
2. Government should provide technological gadgets that could help to improve digital communication in the classrooms

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