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EVALUATION OF STUDENTS' RETENTION AND ACADEMIC PERFORMANCE IN PRE- AND POST-EXPOSURE TO MARKER-BASED AND MARKERLESS AUGMENTED REALITY

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Abstract

Education plays a critical role in society, and educators use different methods, including augmented realities, to improve learning outcomes and students' academic performance. The focus of this study was to examine the impact of marker-based and markerless augmented reality on students' performance in selected colleges of education in North-Central Nigeria. The study adopted a quasi-experimental research design to survey 326 biology students using a random sampling method. The study used a well-structured questionnaire to assess retention and achievement level in pre-and-post exposure to marker-based and markerless augmented reality. The data were analysed using the Statistical Package for Social Sciences (SPSS). The results indicated that the mean retention and achievement scores in post-exposure to marker-based and markerless augmented reality were 87.91 and 77.35 against 85.01 and 81.15. The control group had mean retention and achievement scores of 59.70 and 59.79. The differences between the mean retention and achievement scores in the pre-exposure and post-exposure were significant at $p \leq 0.05$. The result shows that the correlation coefficient was 0.796 at ≤ 0.05, while the ANCOVA result was 7.461. This study concluded that the marker-based method helped to improve the students' retention and academic performance in the selected colleges of education.

Keywords
Augmented reality, retention, Academic performance

Introduction

In all facets of human society, education plays a crucial, and it is mainly responsible for the rise of human civilization, economic development and technological advancement. Learners' level of knowledge and capacity to apply what they learnt to life endeavours, in and outside the classroom, is critical to their success. An educated individual can understand their rights and analyze their surroundings more critically and effectively. Hence, having adequate education becomes a potent tool in the struggle against poverty, crime and political oppression (Hinton, 2017). According to Cimatti (2016), everyone has the opportunity to learn soft skills and gain new knowledge that will help them live better lives through continued education.

Education promotes a healthy lifestyle, making it simpler to address issues like the general ill-health of people and entire communities (Wilkinson, 2020). Attending a theatre, an exhibition, or a concert enhances and makes one happy while at the same time bettering the career chances in industries that

are continually in need of expertise depend heavily on education. Investing in education helps society become more conscious of pressing issues like environmental preservation and global warming (Karataş and Karataş, (2016). Every person has the potential to alter the world, but the way this alteration affects society or an individual depends on individual aims influenced by their level of education. Education is a long-term investment in the welfare of all societal members. Investing in education helps society become more conscious of pressing issues like environmental preservation and global warming (Kobori *et al.*, 2016).

The role of education in the lives of individuals and society is not enough to emphasize due to its importance. As a result, educators have continued to devise means to improve teaching methods and learning outcomes in formal and informal settings. Most educators hope to continue the discussion that supports learning outcomes and academic performance through continuous professional development (CPD). Also, educators have continued to practice ways to improve their instructional skills and capabilities. The word "practice" in educational discussion refers to the activities teachers or educators engage in to improve instructions, preserve teaching and hone their instructional skills. Some educators believe that teaching is a personal task, while others opined that it is a collaborative activity. For instance, Richards *et al.* (2018) opined that teaching was an individual activity than a collaborative one, while Kern *et al.* (2021) stated that teaching should be a collective task. Kern *et al.* (2021) make a case for K–12 physical educators who toil in isolation, claiming that physical education instructors frequently labour in remote locations, something they thought could be resolved through connection and collaboration.

One major challenge to improving learning outcomes is the difficulties in enhancing learning results, which augmented reality technologies address in the education industry (Lu and Liu, 2015). Augmented reality is an integrated digital information system into instructional materials or their use to bring the users' teaching or learning environment to life in real-time. Unlike virtual reality, which creates artificial environments, augmented reality creates a real-world environment with generated perceptual information overlaid to give the users a real-time experience (Nayyar *et al.*, 2018).

There are six different types of augmented reality classified into triggered and view-based augmentation. Triggers in augmented reality are stimuli that initiate augmentation, while view-based augmented reality is digitized augmentations without reference to the augmented (Edwards-Stewart *et al.*, 2016). Triggered augmented reality is sub-classified into marker-based, markerless, dynamic and complex augmentations, while view-based augmented reality is sub-classified into indirect and non-specific digital augmented reality. Application of any of these types of augmented reality can improve learning outcomes and help students to develop specialized knowledge.

The first group of students to adopt augmented reality are called the digital natives—these people who embrace the use of new technologies become the first customers. This group believed that augmented realities are tools that should be easily accessible in the current portfolio. The second group is the faculty, which consists of academic experts who may have to or must undergo training before incorporating these technologies into their teaching strategies as solutions essential for success (Fernandez, 2017). According to Ko and Rossen (2017), nobody is more qualified to identify the areas where a student needs extra assistance than the professors. Thus, the professors occupy sections of society where these learning opportunities with AR would be most beneficial and complementary. The third group are institutions which must stake a wager on these technologies and incorporate them into their models of educational innovation. The effort of institutions in adopting augmented reality will focus on delivering good training that will increase the quality of education rather than the highest degree. The institutions can achieve this by simply making trial gadgets available for users. The manufacturers of technological tools influenced the education industry because their product users and events all serve as building blocks for the growth of these new tools.

One thing to grasp about augmented reality is that they are tools with technological potential rather than gadgets or even present applications. The ultimate objective is to improve student outcomes throughout the entire educational process, in which the students are critical stakeholders. The sole goal of these tools is to increase the proportion of students

who can obtain the minimal information required from instructional materials by developing competencies. Every day, millions of specialists across thousands of organizations strive to make augmented reality come alive. Of all other ground-breaking technological innovations, augmented reality is only a tool to increase students' understanding and academic outcomes. Also, augmented reality improves the instructional skills and teaching methodologies of teachers. This study evaluates retentions and academic achievement scores of NCE biology students in exposure to marker-based and markerless augmented realities in North-Central Nigeria.

Statement of the Research Problem

The challenges of current educational practice are many, and they are primarily associated with methods of instruction, teaching materials, the teacher and the learners. The decisions regarding the choice of subject matter, instructional strategies, and delivery formats are frequently undertaken at various educational levels and across subject areas without conceptual justification. This lack of conceptual validation does not necessarily imply that the educators lack understanding of the concepts. Rather, it emphasizes the necessity of updating teaching methods or approaches to material delivery, including adopting technologies that address the current challenges in understudied areas or hard-to-grab concepts. Areas that have faced the most challenge in the education sector are students' academic performance and learning outcomes. According to Lu and Liu (2015), one major challenge to improving learning outcomes is the difficulties in enhancing learning results. Al-Hariri and Al-Haltami (2017) postulated that adopting technologies could address some of the challenges in the education sector. Augmented reality was pointed out as one such technology by Nayyar *et al.* (2018). Augmented reality is an integrated digital information system into instructional materials or their use to bring the users' teaching or learning environment to life in real-time. This study evaluates retentions and academic achievement scores of NCE biology students in exposure to marker-based and markerless augmented realities in North-Central Nigeria.

Aim of the Research

The aim of this study was to evaluate the retention and academic achievement scores of NCE biology students in exposure to marker-based and markerless augmented realities in North-Central Nigeria.

Objectives of the Study

The objectives of this study are to:

i. evaluate the impact of marker-based and markerless augmented reality on students' retention in the selected colleges of education in North – Central, Nigeria.

ii. determine the impact of marker-based and markerless augmented reality on students' achievement in selected colleges of education in North – Central, Nigeria.

iii. examine the students motivation toward the marker-based and markerless augmented reality in the selected colleges of education in North – Central, Nigeria.

Hypothesis

The study uses the null and the alternative hypothesis in examining the impact of marker-based and markerless augmented reality on students mean retention and achievement scores in the selected colleges of education in North-Central Nigeria.

Null hypothesis (H_0): the use of marker-based and markerless augmented reality in teaching biological association has no significant impact on students mean retention and achievement scores in selected colleges of education in North-Central Nigeria.

Alternative hypothesis (H_A): the use of marker-based and markerless augmented reality in teaching biological association has significant impact on students mean retention and achievement scores in selected colleges of education in North-Central Nigeria.

METHODOLOGY OF THE STUDY

The study adopted a quasi-experimental research design to survey 326 students out of the total population of 3152 Nigeria Certificate in Education (NCE) Biology students in North Central, Nigeria. The 326 students were made up of 162 males and 164 females from three selected Colleges of Education in North–Central, Nigeria. The study employed a random sampling method in administering a well-structured questionnaire designed to assess the level of retention and

achievement before and after exposure to the two types of augmented reality. The experimental groups were labelled groups I, II and III. Group I and II were exposed to marker-based and markerless augmented reality while group III (the control group) were taught with the conventional lecture method.

The questionnaire instrument used to study the Biology Achievement Test (BAT) of the students contained 50 – questions (item) covering topics on Biological Association. The instrument was subjected to face and content validation by two experts from the Science Education Department of the Federal University of Technology, Minna. A pilot study was conducted for the group outside the target population but the same NCE student to determine the reliability of the study instrument. The test and re-test method was used in the administration (BAT) to NCE 1 Biology education students within the interval of two weeks. The administration of the study questionnaire was done in a pre-and post-test mode for all three groups for both student retention and achievement. The instrument was administered to the two experimental groups and the control group. The first group were exposed to Marker-Based Augmented Reality, the second group to Markerless Augmented Reality and the Conventional Lecture Method (CLM).

The data obtained were analysed for mean, standard deviation and statistical significance using the Statistical Package for Social Sciences (SPSS) version 23.0. The data collected from this research work were statistically analyzed using descriptive and inferential statistics. The Pearson Product Moment Correlation (PPMC) feature of the SPSS was applied to determine the reliability coefficient of the study instrument. The Analysis of Covariance (ANCOVA) feature of the SPSS was used to test the significance level of mean retention and mean achievement scores obtained for each group of students in the pre-and post-test manner.

RESULTS

Objective one of this study examined the mean retention scores of students taught biological association using marker-based and markerless augmented reality methods. The mean and standard deviation result in Table 4.1 shows marker-based and markerless augmented reality and the control group. The marker-based augmented reality had a mean retention score of 85.01 and 11.27 in the pre-exposure and 87.91 and 15.43 in the post-test. The result indicates a mean gain of 2.9 points increases in retention, representing about a 3.41 % gain in students' retention ability after exposure to the marker-based augmented reality teaching method. The students taught with the markerless augmented reality had mean retention scores and standard deviation of 81.15 and 15.02 in the pre-test and 77.35 and 21.07 in the post-test. The result indicates a 3.8-point loss in retention, representing about a 4.68 % loss in students' ability to retain after being exposed to markerless augmented reality. The control group taught biological association with the conventional teaching method had mean and standard deviation scores of 59.70 and 14.96 in the pre-exposure and 72.69 and 8.63 in the post-exposure, representing a gain of 12.99-points. The 12.99 point gain in mean retention score represents about 21.76 %, indicating a significant increase in the group of students' ability to remember the taught concept. These results imply that students taught biological associations using the three methods have different retention abilities in pre-and post-exposure to the teaching method. While the marker-based and conventional methods produce a 3.41 % and 21.76 % gain in students' ability to retain, the markerless augmented reality resulted in a 4.68 % loss in retention ability. These results mean that the students remembered more of the concepts taught through conventional and marker-based methods while losing retention with markerless augmented reality.

Table 1: Retention Scores of the Students Taught Biological Associations Using the Three Teaching Methods

Experiment Groups	N	Pretest		Posttest		Difference	Comment
		$\bar{x}_1$	SD	$\bar{x}_2$	SD	$\bar{x}_2 - \bar{x}_1$	Gain or Loss
Marker-Based	115	85.01	11.27	87.91	15.43	2.90	Gain
Markerless	110	81.15	15.05	77.35	21.07	-3.80	Loss
Control Group	101	59.70	14.96	72.69	8.83	12.99	Gain
Column Sum	**326**	**225.86**	**41.28**	**237.95**	**45.33**	**12.09**	**2 Gain 1Loss**

Key: N= Number in samples, $\bar{x}$ = Mean, SD= Standard Deviations

Objective two of this study examined the mean achievement scores of students taught biological associations using marker-based and markerless augmented reality methods. Table 4.2 shows the mean and standard deviation of the three groups in the pre and post-exposure to the three different teaching methods. The mean achievement score and standard deviation for the group taught with marker-based is 42.80 with a standard deviation of 18.21 in the pretest, while the mean achievement score of the post-exposure is 85.01 with SD of 11.27. The mean achievement result indicated again 42.21 points, which represents a mean achievement gain of 98.62 %. This result revealed that the student's mean achievement scores increased by almost 100 % after exposure to the marker-based augmented reality teaching method. The group taught with markerless augmented reality had a mean achievement score of 42.82 with an SD of 18.47 in the pretest, while the mean achievement score of students in the post-exposure was 81.15 with an SD of 15.02. This result indicates that the mean achievement gain is 38.33 points, which represents an 89.51 % gain in achievement score. This result implies that the students taught biological association with markerless augmented reality had an 89.51 % increase in mean achievement score after exposure to the markerless augmented reality. The students lectured the biological association with the conventional teaching method, which served as the control group, had a mean achievement score (MAS) of 34.79 with a standard deviation (SD) of 14.838 in the pre-exposure while the means achievement score in post-exposure increased to 59.70 with an SD of 14.96. The mean achievement gain of the group was 24.91 points, which indicates about 41.73 % gain in MAS in the posttest. These results showed that the students taught biological association with marker-based augmented reality had higher mean achievement scores when compared to the markerless augmented reality and the conventional methods. This implies that marker-based augmented reality outperformed markerless and conventional teaching methods.

Table 2: Achievement Scores of the Students Taught Biological Association Using the Three Teaching Methods

Experiment Groups	N	Pretest		Posttest		Difference	Comment
		$\bar{x}_1$	SD	$\bar{x}_2$	SD	$\bar{x}_2 - \bar{x}_1$	Gain or Loss
Marker-Based	115	42.80	18.21	85.01	11.27	42.21	Gain
Markerless	110	42.82	18.47	81.15	15.02	38.33	Gain
Control Group	101	34.79	14.84	59.70	14.96	24.91	Gain
Column Sum	**326**	**120.14**	**51.52**	**225.86**	**41.25**	**105.45**	**All**

Key: N= Number in samples, $\bar{x}$ = Mean, SD= Standard Deviations

The result in Figure 1 represents the per cent gain/loss in achievement and retention scores of the students taught biological associations using three different teaching methods. The marker-based teaching method had the highest percentage of achievement scores (98.62 %) in the post-exposure, followed by markerless (89.51 %), while the conventional teaching method had the least achievement scores (41.73 %). The mean retention score results show that the students taught biological association with the conventional teaching method had the highest retention score of 21.76 %, followed by 3.41 % obtained for the marker-based and the markerless augmented reality teaching method recorded a -4.68 % loss in the retention score of the students. The results imply that marker-based augmented reality performed better in achievement, while the conventional teaching method performed better in retention.

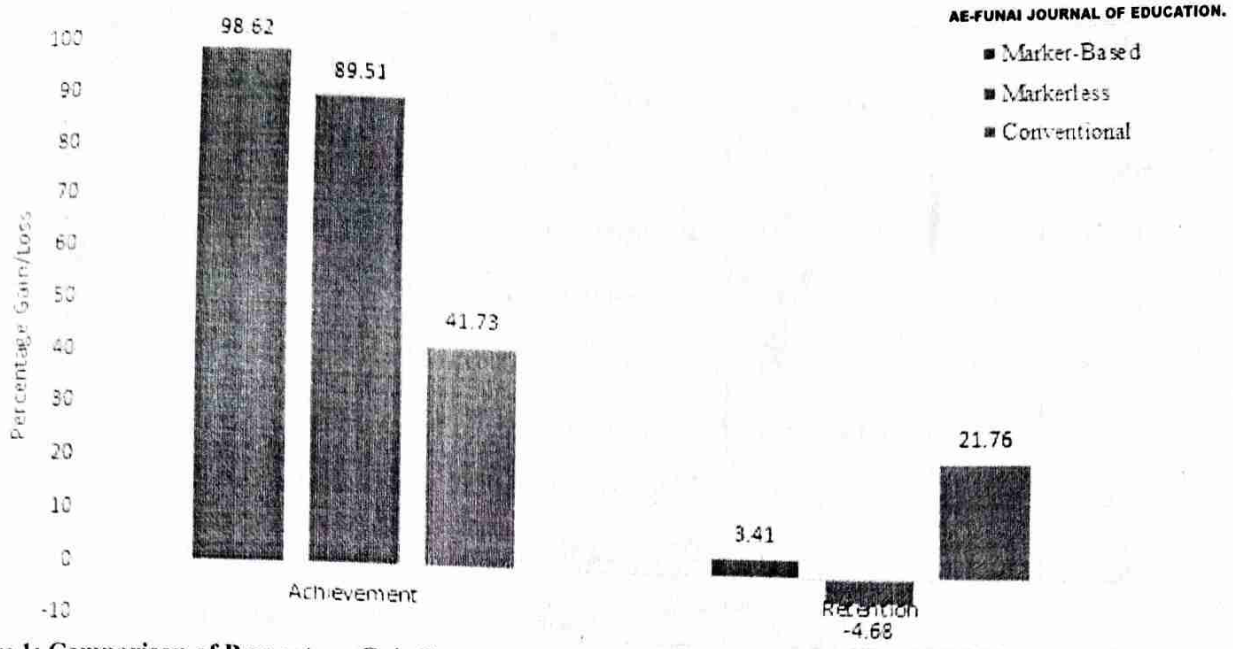

Figure 1: Comparison of Percentage Gain/Loss in Achievement and Retention in Post-exposure to the Three Teaching Methods

Objective three of this study was divided into two sub-objectives labelled A and B. Objective three A evaluate the motivation of students exposed to the marker-based augmented reality. The result in Table 4.3 shows the mean and standard deviation of respondents exposed to marker-based augmented reality. The result revealed that the mean responses range from 2.37 to 4.69, which indicates negative and positive responses. The result showed that the marker-based AR attracted the attention of students relevant to the concepts taught. The marker-based augmented reality increased the students' confidence in learning the biological concept and satisfied their desire to learn. The cumulative mean response of the students was 3.54, which represents the mean decision of the students. Since the mean cumulative decision is above the 3.0 decision mean set by the study, it implies that the respondents agreed with the statements of the study. Hence, students exposed to biological association concepts using marker-based augmented reality had a high level of motivation.

Table 3: Respondents' Opinion Based on Post-Exposure Experience on Marker-Based Augmented Reality Method of Teaching

S/N	Statements	N	$\bar{x}$	SD	Decision
1	The use of AR teaching media arouses my attention in learning Biological associations.	115	4.69	.552	Agreed
2	The use of AR teaching media doesn't arouse my curiosit y to learn biological association.	115	2.66	1.235	Disagreed
3	The use of AR teaching media makes Biological associations more relevant.	115	4.42	.761	Agreed
4	The use of AR teaching media does not stimulate Biology students to attend the lectures.	115	2.64	1.149	Disagreed
5	With the use of AR teaching media students are now motivated to learn Biology.	115	4.42	.816	Agreed
6	The use of AR teaching media does not improve my understanding of Biology.	115	2.43	1.178	Disagreed
7	The use of AR teaching media has helped my assimilation in Biology.	115	4.50	.777	Agreed
8	The use of AR teaching media does not make learning of Biology less ambiguous.	115	2.62	1.089	Disagreed
9	The use of AR teaching media has contributed towards my performance in Biology.	115	4.49	.776	Agreed

10	With the use of AR teaching media Biology students are not motivated to put in more effort in their study.	115	2.49	1.079	Disagreed
11	The use of AR teaching media arouses the believe that I can do better in Biology.	115	4.68	.615	Agreed
12	The use of AR teaching media does not arouse my interest in personal study of Biology.	115	2.49	1.054	Disagreed
13	The use of AR teaching media has increased my understanding in Biology.	115	4.58	.713	Agreed
14	The use of AR teaching media does not reduce fear of poor performance and failure in Biology.	115	2.77	.930	Disagreed
15	With the use of AR teaching media students are now seeing Biology as a simple subject.	115	4.43	.889	Agreed
16	The use of AR teaching media has not improved students experience in learning Biology.	115	2.64	1.201	Disagreed
17	The use of AR teaching media improves the performance of students in tests and examinations in Biology.	115	4.37	.863	Agreed
18	The use of AR teaching media does not enable the Biology course outline for the semester to be fulfilled.	115	2.57	.900	Disagreed
19	The use of AR teaching media has contributed towards student's attendance to lectures at the end of the semester.	115	4.46	.958	Agreed
20	With the use of AR teaching media Biology students are not fulfilled with the outcome of the learning.	115	2.37	1.021	Disagreed
	Cumulative Mean		**3.54**		

Key: AR= Augmented Reality, Decision mean=3.0, N, Sample size, $\overline{X}$ = Mean, SD= Standard Deviations, 1 – 5 = Attention; 6 – 10 = Relevance; 11 – 15 = Confidence; 16 – 20 = Satisfaction

Objective three B of the study evaluate the motivation of students exposed to biological associations using markerless augmented reality. The result in Table 4.4 shows the mean and standard deviation of participating students exposed to markerless augmented reality. The table reveals that the mean response ranges from 2.12 to 4.87, representing negative and positive motivation. The markerless augmented reality increased students' curiosity in learning relevant Biology concepts, increased students' confidence and satisfied their curiosity about the taught concept. The cumulative mean response of the student was 3.70, which is above the 3.0 decision mean set by the study. Since the cumulative mean is higher than the decision mean, it implies that the students agreed with the statements. Hence, students exposed to the concept of biological associations using markerless augmented reality had higher motivation.

Table 4: Respondents' Opinion Based on Post-Exposure Experience on Markerless Augmented Reality Method of Teaching

S/N	Statements	N	$\overline{X}$	SD	Decision
1	The use of AR teaching media arouses my attention in learning Biological associations.	110	4.87	.335	Agreed
2	The use of AR teaching media doesn't arouse my curiosity to learn Biological associations.	110	3.01	.972	Agreed
3	The use of AR teaching media makes Biological associations more relevant.	110	4.72	.544	Agreed
4	The use of AR teaching media does not stimulate Biology students to attend the lectures.	110	3.56	.991	Agreed
5	With the use of AR teaching media students are now motivated to learn Biology.	110	4.75	.642	Agreed
6	The use of AR teaching media does not improve my understanding of Biology.	110	3.47	1.209	Agreed
7	The use of AR teaching media has helped my assimilation in Biology.	110	4.74	.501	Agreed
8	The use of AR teaching media does not make learning of Biology less ambiguous.	110	3.01	.818	Agreed

9	The use of AR teaching media has contributed towards my performance in Biology.	110	4.70	.599	Agreed
10	With the use of AR teaching media Biology students are not motivated to put in more effort in their study.	110	2.18	.826	Agreed
11	The use of AR teaching media arouses the believe that I can do better in Biology.	110	4.80	.521	Agreed
12	The use of AR teaching media does not arouse my interest in personal study of Biology.	110	2.75	.744	Disagreed
13	The use of AR teaching media has increased my understanding in Biology.	110	4.64	.726	Agreed
14	The use of AR teaching media does not reduce fear of poor performance and failure in Biology.	110	2.17	.702	Disagreed
15	With the use of AR teaching media students are now seeing Biology as a simple subject.	110	4.75	.638	Agreed
16	The use of AR media do not improved the learning experience of the students in Biology.	110	2.14	.710	Disagreed
17	The use of AR teaching media improves the performance of students in tests and examinations in Biology.	110	4.12	.377	Agreed
18	The use of AR teaching media does not enable the Biology course outline for the semester to be fulfilled.	110	2.85	.719	Disagreed
19	The use of AR media in teaching contributed towards student's attendance in lectures at the end of the semester.	110	4.65	.698	Agreed
20	With the use of AR teaching media Biology students are no t fulfilled with the outcome of the learning.	110	2.22	.759	Disagreed
	Cumulative Mean Score for Markerless Augmented Reality		**3.70**		

Key: *AR= Augmented Reality* Decision mean=3.0, N, Sample size, X = Mean, SD= Standard Deviations; 1 – 5 = Attention; 6 – 10 = Relevance; 11 – 15 = Confidence; 16 – 20 = Satisfaction.

Testing of Hypotheses

The results in Table 4.5 show the comparison of mean achievement score of the marker-based, markerless and the control groups. The result indicated that there is significant difference between the three with F-value of ($F_{(2,323)}$) 7.461 at $P \leq 0.01$ and 0.05. The significant difference observed in the mean achievement score of students after exposure to treatment conditions may be attributed to the treatment or other factors. One of such factors that may be responsible for the significance is the original mean achievement score of the students which indicated that the mean score of the group were not the same from the start of the experiment.

Table 5: Comparison of Mean Achievement Scores of Students Taught Biological Association Using the Three Teaching Methods

Source of Variation	Sum of Squares	df	Mean Square	F-value	P-value
Between Groups	4480.136	2	2240.068	7.461	.001
Within Groups	96977.397	323	300.240		
Total	101457.534	325			

The difference in the means achievement scores is significant at 0.05 level.

In order to ascertain the validity of the significance from the above ANCOVA was conducted to examine the differences in the mean achievement scores of students taught Biology course using the marker-based and markerless augmented reality and the control group. The result in Table 4.6 revealed that the F-value of ($F_{(2,323)}$) 99.332 was significant at $P \leq 0.01$ and 0.05. This indicates that there was a significant difference in the mean achievement scores of students taught Biological associations using marker-based and markerless augmented reality in Colleges of Education in North – Central, Nigeria. The size effect revealed that there was a moderate difference (partial $n^2_p = .382$) between the groups which led to the rejection of hypothesis one.

Table 6: Normalized Mean Achievement Scores of Students Exposed to Marker-Based and Markerless Augmented Reality

Source	Sum of Squares	df	Mean Square	F-value	P-value
Corrected Model	39115.013[a]	3	13038.338	68.348	.000
Intercept	294188.818	1	294188.818	1542.153	.000
Covariate (Achievement)	40.138	1	40.138	.210	.647
*Achievement	37897.991	2	18948.995	99.332	.000
Error	61426.315	322	190.765		
Total	1976987.000	326			
Corrected Total	100541.328	325			

The difference in the means achievement scores is significant at 0.05 level.

In order to find the point of difference as indicated by ANCOVA, a Sidak pairwise analysis was conducted. The result of the pairwise comparison in Table 4.6 showed that there was significant difference ($P \leq 0.05$) between the control group and the group taught with marker-based augmented reality. Also, the pairwise comparison shows significance between the group of students taught with markerless augmented reality method and those taught with conventional method (control group). The pairwise comparison show no significant difference in the mean achievement score between the groups taught with the marker-based and the markerless augmented realities. The results indicated that the marker-based and the markerless augmented reality methods of instructions have impacted positively on the achievement score of the students.

Table 7: Sidak Post-hoc Pairwise Comparison of the Means Achievement Scores of Students Taught Biological Association Using the Three Teaching Methods

Method I	Method J	Mean Difference (I-J)	Std. Error	Sig.[b]
Control Group	Marker-based	-25.469*	1.917	0.000
	Markerless	-21.615*	1.936	0.000
Marker-based	Control Group	25.469*	1.917	0.000
	Markerless	3.854	1.842	0.108
Markerless	Control Group	21.615	1.936	0.000
	Marker-based	-3.854	1.842	0.108

The difference in the mean achievement score is significant at 0.05 level.

To ascertain the validity of the significance from the above analysis of covariate (ANCOVA) was conducted to examine the differences in the mean retention scores of students taught Biology associations using the marker-based and markerless augmented reality and the control group. The result in Table 4.8 revealed that the F-value of ($F_{(2,323)}$) 15.220 was significant at $P \leq 0.01$ and 0.05. This result indicates that there was a significant difference in the mean retention scores of students taught Biological associations using marker-based and markerless augmented reality in Colleges of Education in North – Central, Nigeria. The result of the size effect revealed that there was a small difference (partial $n^2_p = .086$) between the groups which led to the rejection of hypothesis two.

Table 8: Normalized Mean Retention Scores of Students Taught Biological Associations Using the Three Teaching Methods

Source	Sum of Squares	Df	Mean Square	F-value	P-value
Corrected Model	13948.110[a]	3	4649.370	18.183	.000
Intercept	53996.011	1	53996.011	211.174	.000
Covariate (Retention)	623.770	1	623.770	2.440	.119
*Retention	7783.288	2	3891.644	15.220	.000*
Error	82333.718	322	255.695		
Total	2163526.000	326			
Corrected Total	96281.828	325			

The difference in the means retention scores is significant at 0.05 level.

In bid to find the point of difference as indicated by ANCOVA, a Sidak pairwise analysis was conducted. The result of the pairwise comparison of the mean retention scores in Table 4.8 showed that there was significant difference ($P \leq 0.05$) between the control group and the group taught with marker-based augmented reality. Also, the pairwise comparison of the means retention score shows significance between the group of students taught with markerless augmented reality method and those taught with conventional method (control group). The pairwise comparison show no significant difference in the mean retention score between the groups taught with the marker-based and the markerless augmented realities. The results indicated that the marker-based and the markerless augmented reality methods of instructions have impacted positively on the mean retention score of the students.

Table 9: Sidak Post-hoc Pairwise Comparison of Means Retention Scores of Students Taught Biological Association Using the three Teaching Methods

Method I	Method J	Mean Difference (I-J)	Std. Error	Sig.[b]
Control Group	Marker-based	-12.671*	2.724	0.000
	Markerless	-2.491	2.602	0.711
Marker-based	Control Group	12.671*	2.724	0.000
	Markerless	10.179*	2.147	0.000
Markerless	Control Group	2.491	2.602	0.711
	Marker-based	-10.179	2.147	0.000

The difference in the means retention scores is significant at 0.05 level.

Discussion of Findings

This study found statistical significance between the means achievement scores of students taught biological associations using marker-based and markerless augmented reality teaching methods. The group of students taught with marker-based augmented reality had higher achievement scores than those taught using markerless augmented reality and conventional methods. The finding was validated by the test of hypothesis carried out on the mean achievement scores with a moderate size effect. The pairwise comparison also revealed that students taught biological associations using a marker-based teaching method achieved better results than those taught with markerless augmented reality. The underlying reason behind the higher achievement score of students exposed to marker-based augmented reality was based on the fact that tagged images, objects and locations brought to life the concept that was taught with interactive digital content. Kysela and Štorková (2015) shared this view and encouraged the use of augmented reality to improve students' performance and learning outcomes. The video, animations and 3D scenes without the need for connection to Global Positioning System (GPS) and WiFi positioning system made the associations explicit and self-explanatory, thereby increasing the student's understanding and improving their academic performance.

Advocates of augmented reality like Kysela and Štorková (2015), Zhao (2018), and Köse and Güner-Yildiz (2021) believe that the use of augmented reality technology in teaching or as a teaching aid help to engage students not only through the sense of hearing but also through the sense of sight, thereby deepening concentration and understanding. Most theorist educationists believe that engaging more senses in learning a particular subject lead to better outcomes and performance of the students. The reason is that content augmentation helps the students see the pictures and images of the biological association. Hence, it makes the learning process both simplified and engaging.

These findings were consistent with the findings of Schlesinger *et al.* (2021), which showed that students performed better and had a high mean score on learnability and satisfaction when taught using the AR-SiS application. Yuliono *et al.* (2018) also reported similar findings when they studied the prominent role of augmented reality. The study stated that the application of augmented reality improved students' knowledge and understanding of the materials and enhanced learning outcomes, pedagogical processes and interactions between student-student, teacher-student and the student-material. In another study, Safadel and White (2019) found that augmented reality supported learning on the physical, cognitive, and sociocultural dimensions. Safadel and White linked the significant difference in the mean achievement and satisfaction to media usability, perception and apprehension created by the virtual aids with the use of 2D and augmented reality. The finding also agrees with Önal and Önal (2021). Onal and Önal (2021) found significant differences between pre-and post-test results of achievement and interest in astronomy in favour of the experimental group. The conclusion of Onal and Onal supported the use of augmented reality in teaching and learning activities because of the positive impact on the experimental groups. Students taught with augmented reality always do better in mean achievement scores, satisfaction and interest in learning.

On students' retention, this study found that students taught biological associations using marker-based augmented reality had significantly higher retention ability than those taught using markerless augmented reality and conventional. The corresponding null hypothesis supported this finding, which indicated that the difference in the mean retention scores of students was statistically significant. The findings of the pairwise comparison also confirmed the significance of the pre-and post-test results. It showed that the marker-based and markerless augmented reality contributed to higher retentions when compared to the control group (conventional method). This finding agrees with Yiu and Chen (2021). Yiu and Chen (2021) stated that the application of augmented reality enhances interactivity, remembrance and imaginability. The students were able to visualise the taught materials at macromolecular. It was also consistent with the finding of Reeves *et al.* (2021), who found that there is a move towards significance with the combination of both lectures and the augmented reality session. Rukmani and Vasimalairaja (2021) found that augmented reality enhances lateral thinking and academic longevity of high school students of both genders. The adage that 'seeing is believing' plays a significant role in the outcomes obtained from different studies on augmented reality because the students not only heard but also saw the picture shreds of evidence of the taught topic in the classroom. Virtual display ability is a fact that placed augmented reality methods of teaching (whether marker-based or markerless) over conventional methods as used for the control group.

Conclusions

This study concludes based on the findings that the marker-based augmented reality method was more effective in teaching biological association in Colleges of Education in North – Central, Nigeria because it enhanced the students learning outcome. The superiority of marker-based over markerless and conventional method of teaching because it was more responsive to students' learning demand, increased their curiosity and attention to concepts in a more interactive way and eliminated some of the difficulties associated with the traditional learning environment. Markerless augmented reality method was also responsive to students' sensorimotor learning demand and had increased the learning outcome of students compared to the conventional

lecture method. It was more effective than the conventional method because it enhanced learning, achievement and retention. However, the limitation of the markerless augmented reality was that its Global Positioning System (GPS) and WiFi positioning system connectivity were disabled. The disabling of the GPS and WiFi PS reduced its efficiency even though the interactivity and the display of animations, image capture systems and triggers were the same as those of marker-based augmented reality.

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