Journal Homepage: www.ijarpr.com ISSN: 3049-0103 (Online)

International Journal of Advance Research Publication and Reviews

Vol 02, Issue 09, pp 301-309, September 2025

Effect of Virtual Simulation on Students' Interest and Achievement in Chemical Bonding in Calabar Education Zone, Cross River State, Nigeria

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ABSTRACT:

This study investigated the effect of virtual simulation on students' interest and academic achievement in chemical bonding among Senior Secondary One (SS1) students in Calabar Education Zone, Cross River State, Nigeria. A quasi-experimental design was employed, involving 264 students who were exposed to either the virtual simulation method or the conventional teaching method. Data were collected using validated achievement and interest instruments [Chemistry Achievement Test (CAT) and Chemistry Interest Inventory (CII)], and analyzed using descriptive statistics and one-way ANCOVA at 0.05 significant level. The results revealed that students taught with virtual simulations achieved significantly higher academic scores and exhibited greater interest in Chemistry than their counterparts taught using conventional methods. These findings suggest that virtual simulations provide an engaging and effective instructional approach, enhancing both understanding and motivation in science education. Based on the findings, the study recommends the integration of virtual simulation tools into Chemistry teaching to improve student outcomes.

Keywords: Virtual simulation, Chemistry education, Academic achievement, Students' interest, Instructional methods

Introduction:

Science education, particularly Chemistry, often presents challenges due to the abstract nature of its concepts, which can hinder students' understanding, interest, and academic achievement. Traditional teaching methods have been criticized for their limited ability to engage learners and facilitate deep comprehension of complex topics such as chemical bonding. As a result, students often experience low motivation and poor performance in science subjects, which has prompted educators to explore innovative instructional strategies.

Virtual simulation, a technology-enhanced instructional approach, allows students to interact with dynamic models of chemical processes, providing opportunities for visualization and active engagement. Several studies have highlighted the benefits of computer-assisted and simulation-based learning in improving understanding, retention, and interest in science subjects ((De Jong & Joolingen, 2011). By bridging the gap between abstract theory and observable phenomena, virtual simulations offer a promising solution to the persistent challenges in Chemistry education.

Interest is a motivational construct that reflects a student's willingness to engage with academic tasks. Research suggests that interest is a strong predictor of persistence, attention, and long-term learning outcomes (Agbi, 2016; Ifeanacho, 2012). Conventional lecture methods often fail to stimulate interest because they minimize student participation. By contrast, virtual simulations have the potential to increase engagement by making learning more interactive and relatable (Priest, 2017).

Academic achievement in Chemistry refers to the extent to which students attain the set learning objectives, typically measured through standardized tests or examinations. Studies consistently identify chemical bonding as one of the most abstract and difficult topics for secondary school learners (Griffiths & Preston, 2012). Achievement is influenced by instructional strategies; active, technology-enhanced learning tends to promote deeper understanding and retention compared to rote-based lecture methods (Adeoye, 2016; Okoye, 2014).

Several studies have examined how virtual simulations affect learners' interest in science. Njoku (2017) reported that Chemistry students exposed to virtual simulations showed significantly greater interest than those taught with traditional methods. Similarly, Nwagbo (2019) found that visual simulation strategies increased students' motivation and participation in Biology classes. Akabogu (2010) also observed that the use of virtual simulations in Basic Science enhanced students' curiosity and willingness to learn. These findings suggest that simulations create engaging environments that stimulate learners' enthusiasm, supporting the first hypothesis of this study.

Empirical evidence further supports the positive impact of simulations on academic achievement. Peterson, Treagust, and Garnett (2016) demonstrated that computer-based tools helped secondary school students develop better conceptual understanding of covalent bonding. Njoku (2017) reported improved performance in Chemistry practical skills when virtual simulations were employed.

Makransky, Petersen and Klingenberg, (2020) examined how immersive virtual reality (IVR) laboratory simulations can enhance science interest and career aspirations among middle and high school students. The findings indicate that IVR-based learning experiences can significantly increase students' interest in science topics and lead to a notable increase in science aspirations, particularly among 13- to 16-year-old female students. The research highlights the potential of IVR simulations to improve students' situational interest and social outcome expectations related to science education.

Likewise, Okereke and Onwukwe (2011) emphasized that simulations allow learners to test hypotheses and observe outcomes, resulting in higher achievement scores compared to lecture-based teaching. Dange (2018); Agogo and Terngu (2011) highlighted the limitations of lecture methods, stressing the superiority of interactive strategies in promoting meaningful learning. These results reinforce the second hypothesis of this study.

However, the issue of teachers' methods of instruction has remained a recurrent factor affecting students' interest and achievement. The various strategies adopted by teachers have not substantially addressed this challenges. Therefore, there a need to explore innovative approaches that can help mitigate students' lack of interest and poor academic achievement in Chemistry.

This study therefore sought to investigate the effect of virtual simulations on senior secondary school students' interest and academic achievement in chemical bonding. Specifically, the study aimed to determine whether students exposed to virtual simulation would demonstrate higher achievement and interest compared to those taught using conventional methods, and to examine whether gender differences influence these outcomes. The findings of this study are expected to inform teaching practices, curriculum design, and policy decisions aimed at enhancing science education outcomes.

Purpose of the Study: The purpose of this study is to investigate the effect of virtual simulations on students' academic interest and achievement in chemical bonding in Calabar Education Zone, Cross River State Nigeria.

Specifically, the study seeks to:

1. Investigate the effect of virtual simulation and lecture method on students' interest in Chemical bonding.
2. Examine the effect of virtual simulation and lecture method on students' achievement in Chemical bonding

Research questions: Two research questions guided the study:

1. What is the effect of virtual simulation and lecture methods on students' interest in chemical bonding?

2. How do virtual simulation and lecture methods affect students' achievement in chemical bonding?

Null hypotheses: Two null hypotheses was formulated to guide the study:

1. There is no significant difference between the effects of virtual simulation and lecture methods on students' interest in chemical bonding.

2. There is no significant difference between the effects of teaching methods on students' achievement in chemical bonding.

Methodology:

The design of the study is presented symbolically as follows;

Groups	Pretest	Treatment	Posttest	Gender
E1	O1	X1	O2	M
C	O1	X2	O2	F

Where; E1 = experimental group, C = control group, O1 = pre-test for all groups

O2 = post-test for all groups, X1= treatment given to experimental group

X2 = treatment for control group, M = male students, F = female students

The study adopted a quasi-experimental pretest–posttest non-equivalent control group design. One group (experimental) was taught chemical bonding using virtual simulations, while the other group (control) received lecture-based instruction. The population consisted of 4,130 SS1 Chemistry students from 86 public secondary schools in Calabar Education Zone of Cross River State. A sample of 264 students (136 males and 128 females) were drawn from six schools with functional computer facilities, selected through stratified random sampling. Two instruments were used: Chemistry Achievement Test (CAT): 30-item multiple-choice test with a KR-20 reliability index of 0.82 and Chemistry Interest Inventory (CII): 25-item Likert-scale instrument with a Cronbach Alpha reliability index of 0.79. Both groups were taught the same Chemistry content on chemical bonding for four weeks. The experimental group received lessons through computer-based virtual simulations, while the control group was taught with the lecture method. Pretests were administered before instruction and posttests immediately after. Mean and standard deviation were used to answer the research questions, while ANCOVA tested the hypotheses at 0.05 level of significance, using pretest scores as covariates.

Results

General Description of Research Variables.

The descriptive statistics of the research variables are presented in Table 1 and 2, along with their interpretations.

Table 1

Descriptive statistics of study variables by gender.

Variable Name	N	Gender	Mean	Std. dev.	Std. error	Maximum	Minimum
Achievement Pretest	136	Male	15.316	5.061	.434	29	7
	128	Female	14.266	4.478	.396	25	5
	264	**Total**	**14.807**	**4.807**	**.296**	**29**	**5**
Interest Pretest	136	Male	8.360	1.892	.162	12	4
	128	Female	8.188	2.261	.199	15	1
	264	**Total**	**8.277**	**2.077**	**.128**	**15**	**1**

Table 1 presents the mean pre-test scores of male (15.316, SD = 14.266) and female (14.266, SD = 4.478) students. The table also shows the mean interest pre-test scores of (8.360, SD = 1.892) for male students and (8.188, SD = 2.261) for female students. These results indicate that the male students' mean pre-test score was slightly higher than that of the female students. However, the pre-test interest mean scores of both male and female students were observed to be at approximately the same level.

Table 2

Descriptive statistics of the study variables by teaching methods

Variable Name	N	Gender	Mean	Std. dev.	Std. error	Maximum	Minimum
Achievement Pretest	142	Virtual	16.465	4.643	.390	28	7
	122	Conventional	12.877	4.257	.385	29	5
	264	**Total**	**14.807**	**4.807**	**.296**	**29**	**5**
Interest Pretest	142	Virtual	14.061	4.211	.366	25	6
	122	Conventional	10.633	3.618	.304	24	4
	264	**Total**	**12.802**	**4.000**	**.269**	**25**	**4**

Result from Table 2 show that mean achievement pre-test score of students taught with virtual simulation method was 16.465 whereas those taught with the conventional method had a mean score of 12.887. Similarly, the mean interest score of students taught with virtual simulations was 14.06, compared to 10.633 for those taught with the conventional method. These findings suggest that the virtual simulation method was more effective than the conventional method in enhancing

students' achievement. However, the results indicate that students' interest levels may not be strongly influenced by the method of instruction. This provides a basis for further analysis of the research hypotheses.

Hypotheses were formulated and tested at 0.05 level of significant:

Hypothesis one: There is no significant effect of virtual simulations lecture methods on the interest mean scores of students in Chemical Bonding.

To test the hypothesis, one-way ANCOVA was employed, and the results are presented in Table 3.

Table 3

A one-way Analysis of Covariance ANCOVA of students' interest by teaching methods.

Methods	**N**	**Means**	**Std. Dev.**	**Adjusted Mean**	**Std. Error**
Virtual Simulation	142	18.162	4.077	18.201	.481
Conventional	122	13.1803	4.362	12.589	.650
Total	**264**	**15.860**	**4.884**	**15.632**	**.552**

Source	**Type III Sum of squares**	**Df**	**Mean square**	**F**	**p-value**
Corrected Model	1628.801	2	814.400	45.761	.000
Intercept	3737.116	1	3737.116	209.986	.000
Interest Pre-test	.294	1	.294	.017	.898
Method	1624.014	1	1624.135	91.259	.000
Error	4645.014	261	17.797		
Total	72679.000	264			
Corrected Total	6273.814	263			

Source	**Sum of squares**	**Df**	**Mean square**	**F**	**p-value**
Corrected Model	3036.491[9]	2	1518.245	20.533	.000
Intercept	29438.220	1	29438.220	398.120	.000
Achievement Pretest	122.483	1	122.483	1.656	.199
Teaching Methods	2112.668	1	2112.668	28.572	.000
Error	19299.131	261	73.943		

Total	421232.000	264
Corrected Total	**22335.621**	**263**

*Significant at .05 level. R squared = .260 (Adjusted R squared = .254).

Result from Table 3 show that the mean interest score of students taught with virtual simulation method (18.162) was higher than that of students taught with the conventional method (13.180). The p-value (.000) associated with the computed F-values for the corrected model (45.76), intercept (209.986), and teaching method (91.259) were all less than 0.05. Conversely, the p-value (0.898) associated with the computed F-value (0.017) was higher than 0.05. Taken together, these findings suggest that the means that teaching method had a significant effect on students' interest in Chemistry, providing evidence to reject the null hypothesis. However, since the covariate and the adjusted mean were not significant, it was not considered necessary to conduct a post hoc test. This outcome highlights the potential of virtual simulations in fostering greater interest in Chemistry among students and provides a basis for further discussion.

Hypothesis two: There is no significant effect of teaching methods on the achievement mean scores in chemical bonding.

To test the hypothesis, ANCOVA was employed, and the results are presented in Table 4.

Table 4

Analysis of Covariance ANCOVA of students' mean achievement scores taught chemical bonding with virtual simulation and conventional methods.

Methods	N	Means	Std. Dev.	Adjusted Mean	Std Error
Virtual Simulation	142	41.951	7.985	40.092	.520
Conventional	122	35.287	9.285	36.018	.382
Total	**264**	**38.871**	**9.216**	**37.650**	**.486**

*Significant at .05 level. R squared = .136 (Adjusted R squared = .129).

Results from Table 4 show that the mean score for virtual simulation method of (41.951) was higher than that of students taught with the conventional method (35.287). The mean p-value (.000) associated with the computed F-values for the corrected model (20.533), intercept (398.120), and teaching method (28.572) were all less than the 0.05. In contrast, the p-value (.199) associated with the computed F-value for the pre-test (1.656) was greater than 0.05. The adjusted mean scores 40.092 and 36.018 were also not significant. Taken together, these findings suggest that the teaching method had a significant effect on students' academic achievement in chemical bonding, providing evidence to reject the null hypothesis. This finding further reinforces the effectiveness of virtual simulations as an instructional strategy in Chemistry and provides a strong basis for discussion in relation to existing literature.

Discussion of results based on the hypotheses

The first hypothesis stated that there is no significant difference in students' interest in Chemistry when taught using virtual simulation and the conventional method. The results, however, revealed a significant effect of teaching method on students' interest, with those taught using virtual simulations recording higher mean interest scores than their counterparts taught with the conventional method. This suggests that virtual simulations may provide a more engaging

and interactive learning environment that stimulates curiosity and sustains students' attention. This finding is consistent with the work of Yusuf (2019), who reported that computer-based instructional strategies significantly enhance students' interest and motivation in science subjects. Similarly, Mbam, (2015) emphasized that technology-driven methods promote active learning, which is critical for sustaining students' interest in Chemistry.

The second hypothesis stated that there is no significant difference in students' academic achievement in Chemistry when taught using virtual simulation and the conventional method. The results demonstrated that students taught with the virtual simulation method performed significantly better than those taught with the conventional method, thereby leading to the rejection of the null hypothesis. This indicates that virtual simulations were more effective in enhancing students' understanding of abstract concepts such as chemical bonding, which are often considered difficult to learn through traditional teaching approaches.

This finding corroborates earlier studies by Strangman & Hall (2013), who observed that students taught with computer-assisted or virtual learning environments achieved higher scores compared to those taught with conventional approaches. According to Kozma and Russell (2017), virtual simulations help to concretize abstract scientific concepts, enabling students to visualize molecular interactions and chemical processes that cannot be easily demonstrated in a physical classroom.

Taken together, the rejection of both hypotheses underscores the positive influence of virtual simulations on students' learning outcomes in Chemistry. The findings suggest that virtual simulations not only improve achievement but also foster greater interest in the subject, making them a valuable tool for addressing persistent challenges of low performance and declining motivation in science education. These results align with the position of Priest (2017), who argued that technology-enhanced instruction provides learners with opportunities for deeper conceptual understanding, improved retention, and greater enthusiasm for learning.

The findings demonstrate that virtual simulation significantly improved both students' interest and achievement in chemical bonding compared to the lecture method. These results align with earlier studies (Njoku, 2017; Nwagbo, 2019) that reported enhanced engagement and performance when simulations were used in science classrooms. The findings support theoretical perspectives that emphasize learning through experience and observation (Makransky, Petersen & Klingenberg, 2020). By providing interactive environments, simulations make abstract Chemistry concepts tangible, motivating learners and promoting deeper understanding.

Conclusion:

The study revealed that students taught chemical bonding using the virtual simulation method achieved higher academic scores and exhibited greater interest in Chemistry than those taught with the conventional method. This indicates that virtual simulations are more effective in enhancing both students' understanding and engagement in the subject.

Recommendations

1. Teachers should incorporate virtual simulations into Chemistry lessons to improve students' comprehension of abstract concepts and sustain interest.

2. Curriculum developers should integrate technology-enhanced learning tools, such as virtual simulations, into the senior secondary school Chemistry curriculum.

3. Policymakers should provide resources and training for schools to adopt virtual simulation tools to enhance science education outcomes.

Implications for research and practice

The findings highlight the potential of virtual simulations to transform science education by bridging the gap between theoretical concepts and practical understanding. Future research can explore the long-term impact of virtual simulations on retention and performance across other scientific disciplines. In practice, integrating such technology-driven strategies can foster a more engaging and effective learning environment, ultimately improving students' academic outcomes and motivation in science subjects.

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