

Impact of Interactive Simulations on Secondary School Chemistry Students' Learning Outcomes in Abuja Municipal Area Council

By

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Abstract

This study investigated the "Impact of Interactive Simulations on Secondary School Chemistry Students' Achievement and Interest in Abuja Municipal Area Council". The sample of the study comprised Two hundred and sixty-four (264; M= 168, F=96) students selected from four co-educational senior secondary schools in Abuja Municipal Area Council. There were one experimental group and a control group. One treatment instrument namely, PhET interactive simulations instructional package was adopted to examine its impact on students' achievement and interest. The research design was a quasi-experimental, pretest posttest control design. The experimental group was taught using PhET interactive simulations package and the control group was taught using lecture method. The Chemistry Achievement Test (CAT) of 20 items was validated by experts for data collection. The reliability of the items instrument was ascertained using Cronbach Alpha formula and a coefficient of 0.826 was obtained. Four (4) hypotheses were formulated and tested at 0.05 alpha levels. The data were analyzed using mean, Standard Deviation and ANCOVA Statistic. The findings of the study revealed that students in experimental group achieved significantly better than their counterpart in the control group. There was statistically no significant difference in the achievement of Male and Female students of experimental group. Also, there was significant mean interest score of experimental group with interest inventory test, the mean difference of strongly agreed and agreed for the PhET interactive simulations out measured the other Likert scale. In addition, there was no significant difference in the mean interest score of male and female students in the group. Based on the findings, it was recommended among others that the use of PhET downloaded interactive simulations for teaching and learning should be encouraged in Nigerian schools.

Keywords: Achievement, Interest, Learning outcomes, Open Educational Resources (OERs), Open source, PhET, Simulations

Introduction

With rapid development in Information and Communication Technology (ICT), the use of technology in learning environment has become a commonplace. ICT addresses visual and auditory senses, it is used in science teaching in many forms such as micro-computer-based laboratories, micro-words, interactive video discs, multimedia, hypermedia and simulations (Koyunlu & Dokme, 2011). Technology is one of the most prevalent tools complementary to innovative instructional models and it has also become one of the most important components in many aspects of our lives. Due to the prevalence of technology in our society, many educators strive to make its integration into education a reality. There are many technology-based learning environments for schools that teach science. Examples include Interactive

Physics, a computer-based Newtonian micro-world (Design Simulation Technologies, 2005-2013), PhET simulations (PhET Interactive Simulations, 2013), interactive simulation programs for physics, chemistry, biology, earth science, and mathematics concepts (Wieman, Adams, Loeblein, & Perkins, 2015).

Simulation is a programme that creates animated, interactive, game – like environments, which focus on connecting real – life phenomena to the underlying science. Within this process, it makes the visual and conceptual models of experts and scientist simple, so that they can be understood by learners (Adams, Reid, LeMaster, McKagan, Perkins, Dubson & Wieman, 2010). There are published simulations available for purchase but many teachers prefer to create their own to suit their purpose, just as PhET interactive simulations (PhET Interactive Simulations, 2013). A well-designed simulation simplifies a real-world system while heightening awareness of the complexity of that system. Students can participate in the simplified system and learn how the real system operates without spending the days, weeks, or years it would take to undergo this experience in the real world (Design Simulation Technologies, 2005-2013).

However, PhET interactive simulations are open educational resources (designed and tested at the University of Colorado at Boulder), which have developed a suite of realistic, open source simulations that cover many main topics of pure science subjects both at the secondary and University levels. These simulations are designed and tested to provide fun, interactive, research-based simulations of physical phenomena in a learning environment (Adams, *et al.* 2010). They can be freely used, shared, or redistributed under the license and animate what is invisible to the eye through the use of graphics and intuitive controls such as click-and-drag manipulation, sliders and radio buttons. As the user manipulates these interactive tools, responses are immediately animated thus effectively illustrating cause-and-effect relationships as well as multiple linked representations (motion of the objects, graphs, number readouts, and other.) (Yeo, 2009).

Chemistry is the branch of science that deals with the study of the structure and composition of matter. Chemistry has often been described as the central science, this is because effective study of chemistry lays a solid foundation for the scientific and technological development of an early learner in the sciences (Omoifo, 2012). It does not just start and end in the classroom or school as often perceived, phenomena in chemistry are practiced in day to day lives in and outside the school, even on social media. Some of the chemistry practices are the process of heating (cooking/warming) of food, the process of washing clothes with soap or detergents, addition of limestone when cooking beans, unripe plantain and many others, the process of putting stainless steel spoon into meat while boiling, the process of separation of kerosene or petrol from water, the process of preparation of pap from grounded maize (corn), the process of spraying insecticides in the house to kill insects, the act of melting ice block into liquid water for the purpose of drinking, preparation of African fufu through cassava, the burning of materials in the presence of air (oxygen), the process of rusting of clean nail when it has been exposed to air and water (chemical change) and so many others, just to mention but a few. This goes to show that many principles in chemistry are applied in day to day activities (Forrester, 2012). The weakness associated with the performance of candidates in chemistry were attributed to lack of relevant textbooks, lack of instructional resources and equipment, inappropriate instructional strategies and methods and inadequate supply of laboratory materials. Again, prominent among the prevalent problems in the school system are interest and gender, according to (2014), interest is a decisive factor in the learning process.

Interest is a persisting tendency to pay attention and enjoy some activities. It is viewed as emotionally oriented behavioural trait which determines students' enthusiasm in tackling educational programmes or other activities (Olayemi, 2014). Galton(2005) stressed interest as that attraction which forces or compels a student to respond to a particular stimulus. To some others, it is a phenomenon that emerges from an individual's interaction with the environment (Agboola & Oloyede, 2007). An interest represented a specific and distinguished relationship between a person and an object. Thus, such object can be concrete, topical, subject-matter or abstract ideas that is a certain part of the cognitively represented environment. One important role of the instructor is to order and structure the learning environment and use of motivational techniques to secure and sustain the attention and interest of the learner (Kalu, 2010). Therefore, interest is an effective behaviour that can be aroused and sustained in teaching and learning through appropriate teaching strategy, students' interest and achievement in any learning activity is sustained by the active involvement of the learner in all aspects of the learning process. Ogbu (2010) emphasized that unless the instructor stimulates students' interest in learning students' achievement will be minimal.

However, it is important to determine whether male and female students show equal interest with the use of PhET interactive simulations method in the teaching of chemistry. As noted, (Post Primary Schools Management Board, 2014), gender is the physical and behavioural difference that distinguishes individual organisms according to their functions in the reproductive process. Boys and girls as groups are interested in different aspects of science, with girls being equally or less interested than boys in some topics in chemistry and Physics (Sjoberg, 2014). It is also suggested that the main reasons for these inconsistencies is related to the type of measure used by the researchers, the nature of the content and of the chemistry curriculum, the instructional techniques often used in the chemistry classrooms, and the students' grade level (Cheung, 2012). Against this background, therefore, the researcher tends to investigate the impacts of PhET interactive simulations on learning outcomes of chemistry students in secondary schools.

Statement of the Research Problem

As important as the Chemistry is and in spite of its day to day applications, students' performance in external examination WAEC and NECO revealed poor performance of students. This is evidenced in WAEC/NECO results from 2013 to 2015. The steady decline in students' performance in chemistry and its related subjects has remained a source of worry to the students, parents, teachers, government and even Non – Governmental Organisations in Nigeria. In addressing this issue, the instructional strategies among other factors have been reported to be a crucial parameter. Researchers (Udo & Eshiet, 2013; LongJohn 2009; Igboegwu 2010) have traced these problems of failure in chemistry to these number of factors; inappropriate instructional strategies and methods and lack of students' interest. Poor and ineffective instructional strategies have been reported by the above-named researchers as the major factor responsible for the consistent poor achievement of students in Chemistry.

Purpose of the study

The aim of the study is to explore the impacts of PhET interactive simulations on Chemistry achievement and interest of Senior Secondary School Students in Abuja Municipal Area Council, Federal Capital Territory, Nigeria.

The following specific objectives were achieved:

- (i) Determined the impact of PhET on students' achievement in chemistry

- (ii) Examined the influence of gender students' achievement in chemistry using interactive simulations
- (iii) Ascertained the impact of PhET on students' interest in chemistry
- (iv) Find out whether gender influences students' interest in chemistry taught with PhET interactive simulations

Research Questions

The following research questions were formulated to guide the study:

- (1) What is the difference in the mean achievement scores of students taught chemistry using PhET interactive simulations and students taught chemistry with lecture method?
- (2) Is there any difference in the mean achievement scores of male and female students taught Chemistry using PhET interactive simulations?
- (3) What is the difference in the mean interest scores of students taught chemistry by PhET interactive simulations and those taught chemistry with lecture methods?
- (4) What is the difference in the mean interest scores of male and female students taught Chemistry using PhET interactive simulations?

Research Hypotheses

The following null hypotheses were formulated and tested at 0.05 level of significance in order to answer the above research questions

Ho₁: There is no significant difference in achievements scores of students taught chemistry using PhET interactive simulations and lecture methods

Ho₂: There is no significant difference in the mean achievement scores of male and female students taught chemistry using PhET interactive simulations

Ho₃: There is no significant difference in the mean interest scores of students taught chemistry using PhET interactive simulations and lecture method

Ho₄: There is no significant difference in the mean interest scores of male and female students taught chemistry using PhET interactive simulations.

Methodology

The research design that was adopted is a quasi – experimental pre-test, posttest, control group design. The design entails the use of non-randomized sample where the researcher cannot randomly sample and assign subjects hence intact classes was used. The sample for this research was 264 SSII science students (Experimental group = 144, 53 male and 91 females while control group = 120, 43 male and 77 female). The study was conducted in four (4) co- educational schools in AMAC, FCT, Abuja. These schools are Government Secondary School wuse zone3, Government Secondary School TundunWada zone4, Model Secondary School, Maitama and Government Secondary School Gwarinpa, FCT, Abuja. Based on the nature of this research, a series of sampling techniques were adopted. Firstly, a purposive random sampling technique was adopted to obtain four schools in AMAC. These schools were purposively sampled based on equivalence (ICT centres, facilities and regular power supply), school type (public school) and candidates' enrolment (enrolling students for WASSCE Chemistry Examination for minimum of ten years). Secondly, the selected four equivalent co-educational schools were divided into two groups; experimental group and the control group through balloting. Two schools were assigned each into experimental group, that is two for PhET interactive simulations while the remaining two for conventional lecture method. However, PhET interactive simulations was assigned to experimental group and

conventional lecture method was equally assigned to control group. Finally, the intact classes were used throughout the research.

The research instrument that was used for this study was a 20- item Chemistry Achievement Test (CAT). The CAT consisted of twenty objective (20) objective items developed on the concepts that was taught with four options letters A – D with only one correct answer included and it was used to obtain data on students' gender and achievement and the same was used for pilot study to determine the reliability of the instrument while Chemistry interest inventory test (CIIT) developed by the researcher, comprised of twenty (20) statements based on five(5) – point Likert scale in which Strongly Agreed(SA) was awarded 5 points, agreed (A) 4 points, undecided (U) was 3 points, disagreed (D) was awarded 2 points and finally, Strongly Disagreed (SD) was 1 point. A mean of 3.00 was taken as acceptable mean for agreement. The CAT questions with the accompanying answers and CIIT were validated by the experts in the subject area. A reliability test was carried out for the instrument using Cronbach Alpha formula and a coefficient of 0.826 was obtained and considered very adequate for research study.

The CAT instrument was administered to the students at first contact with them during the first week of the study as pretest and at the end of three weeks intensive teaching of intact classes by means of dual period of eighty (80) minutes per day in each school. Both the CAT and CIIT were administered to the students in the two instructional strategy groups in all the sampled schools. The CAT questions were collated, marked, scored and later converted to percentage while CIIT were also collated and analysed accordingly.

The data obtained were analysed statistically using inferential and descriptive statistics (Mean and Standard deviation). Analysis of covariance (ANCOVA) statistics using Statistical Package for Social Sciences (SPSS) version 23.0 and the significance of the statistical analyses was ascertained at 0.05 alpha level of significance to test the research hypotheses.

Results

The results of this study are presented in this section

Hypothesis One

There is no significant difference in achievement scores of students taught chemistry using PhET interactive simulations and lecture methods.

This hypothesis was tested using descriptive statistics (mean and standard deviation) and analysis of covariance (ANCOVA). The mean and standard deviation of the posttest mean achievement scores of experimental and the control groups were used as covariance analysis. The result of the analysis is as shown in Table below.

Table1:**Mean and Standard Deviation of the Posttest Mean Achievement scores of Experimental and the Control Groups**

Group	N	Mean(x)	Standard Deviation
Control	120	30.71	10.722
Experimental	144	37.22	12.327
Total	264	34.26	11.930

From the Table 1, it was observed that experimental group benefited from the treatment more than the group counterparts. This is because the students in the experimental group have a higher mean score of 37.22 with standard deviation of 12.327 while control group has a mean score with standard deviation of 10.722

Table2:**ANCOVA Comparison of the Posttest Mean Achievement Scores of Experimental Group and the Control Group**

Source	Sum of Square	df	Mean Square	F	Sig	Partial	Eta
Squared							
Corrected Model	3373.041 ^a	2	1686.521	12.925	.000		0.90
Intercept	25240.842	1	25240.842	193.431	.000		.426
Pre	595.756	1	595.756	4.566	.034		.017
Group	3175.588	1	3175.588	24.336	.000		.085
Error	34057.925	261	130.490				
Total	347325.00	264					
Corrected Total	37430.966	263					

a. R squared=0,90 (Adjusted R squared=0.83) Significant at 0.05 level

The analysis in Table indicated that an F- value of 24.336 and a P-value of 0.000 (F (1,261) =24.336, P<0.05). The outcome of treatment was significant at P<0.05 and hypothesis one (Ho₁) was rejected. This shows that a statistically mean variation exists among the two groups (PhET interactive simulations and Control group).

Hypothesis Two

There is no significant difference in the mean achievement scores of male and female students taught chemistry using PhET interactive simulations.

To find out whether any significant difference existed in the posttest of male and female students taught using PhET interactive simulations, descriptive statistics (mean and standard deviation)

Table 3

Mean and Standard Deviation of the Posttest Mean Achievement Scores of Male and Female Students Taught Chemistry Using PhET interactive simulations

Groups Difference	N	Pretest		Posttest		Mean Gain in
		Mean	Std.	Mean	Std.	
Male	53	25.40	8.969	37.45	9.335	0.366
Female	91	29.12	9.591	37.09	11.500	1.909

From Table4, it was observed that both male and female students benefited from the treatment. The male students, however, has higher mean score of 37.45 with standard deviation of 9.335 while the female students have a mean gain score of 37.07 with standard deviation of 11.500.

Hypothesis Three

There is no significant difference in the mean interest scores of students taught chemistry using PhET interactive simulations and lecture method.

This hypothesis was tested using descriptive statistics (mean and standard deviation)

Table5:

Mean, median, Standard deviation and percentage of the Posttest Mean Interest scores of Experimental and the Control Groups

Items	Std. D.	Mean	Median
1. Chemistry is an abstract subject.	1.475	3.16	3.00
2. Learning chemistry with PhET interactive simulations are better than the lecture method.	1.568	4.20	4.50
3. I had no problem to understand what to do in chemistry.	1.121	3.67	4.00
4. The PhET interactive simulation was meaningful.	0.825	4.44	5.00
5. I am interested more in carrying out experiments of some chemistry concepts using PhET simulations.	0.989	4.32	5.00
6. I was very engaged in trying to understand the underlying chemistry in the PhET interactive simulations.	0.959	4.01	4.00
7. I am interested in studying chemistry using PhET			

interactive simulations.	0.913	4.25	4.00
8. The chemistry discussion/ activities were very interesting.	1.142	4.03	4.00
9. I would like to attend chemistry classes in higher institution using PhET interactive simulations.	1.117	4.17	5.00
10. Chemistry becomes more fun and interesting with PhET simulations than the lecture method.	1.192	4.10	5.00
11. The simulations gave new knowledge in the pH scale (acid - base) and chemical reactions.	0.854	4.37	5.00
12. I felt that the chemistry that was treated in the simulation has become more comprehensible.	1.031	4.03	4.00
13. The chemistry textbook does not help me understand some chemistry concepts.	1.449	2.75	3.00
14. The simulation helped me to connect real life phenomena with underlying chemistry concepts.	0.953	4.03	4.00
15. I enjoy learning about chemistry with simulations outside the school.	1.066	3.93	4.00
16. I prefer learning chemistry with PhET interactive simulations than the lecture method.	1.137	3.94	4.00
17. I believe that Chemistry will be useful for my everyday life.	0.758	4.56	5.00
18. I think chemistry Offers a wide range of cares.	0.813	4.53	5.00
19. Chemistry made me get to better understanding of Some of the things we do at home.	0.856	4.33	5.00
20. I think females perform better than the males in Chemistry.	1.614	3.63	4.00
GRAND TOTAL	1.092	4.02	

From Table 5: the mean scores of items relevant to the PhET interactive simulations are relatively high, above the mean score of 3.00 of the five (5) Likert scale of the research. For instance, the mean scores of item 2, item 4, item 5, item 6, item 7 and item 10 are 4.20, 4.44, 4.32, 4.01, 4.25 and 4.10.

Hypothesis 4

There is no significant difference in the mean interest scores of male and female students taught chemistry using **PhET interactive simulations**.

To find out whether any significance existed in the posttest mean scores of male and female students taught Chemistry using PhET interactive simulation, descriptive statistics (mean and standard deviation) were shown below

Table6

mean and standard deviation of the posttest mean interest scores of male and female students taught Chemistry using PhET interactive simulations strategy

Variable	Gender	No. in samples(N)	Grand Mean(x)	Grand SD.
Experimental	MALE	53	3.7455	1.0763
	FEMALE	91	3.9130	1.10005

From Table 6: it was observed that the mean and standard deviation of both male and female students benefited from the treatment as follows: Experimental Group (Male: $X = 3.7455$, $SD = 1.0763$, Female: $X = 3.9130$, $SD = 1.10005$). The difference between the mean of male and female in experimental group is 0.1675. The mean difference of the mean interest scores shows that there is no significant difference in the mean interest scores of male and female students taught Chemistry using **PhET interactive simulations**.

Summary of Findings

The following findings were made from the study:

1. There was significant difference in the mean achievement scores of students learning Chemistry by means of PhET interactive simulations as well as those learning with lecture method
2. There was no significant difference in the mean achievement scores of male and female students taught Chemistry with the PhET interactive simulations and those learning with conventional method.
3. **Majority of the respondents sampled agreed with the effective use of PhET interactive simulations for learning Chemistry and also capable of arouse students' interest than the conventional lecture method**
4. There was no statistically different in the mean interest scores of respondents of male and female students taught Chemistry by means of PhET interactive simulations.

Discussion

The results of the data analysed showed that experimental group taught Chemistry with PhET interactive simulations achieved better than those taught by means of conventional lecture method. The results further stressed that the variation in the mean achievement of the experimental group and the control was statistically significant and considerable. This outcome is in line with earlier findings of Onwukwe, (2010) who testify that the effects of play simulation and teaching with analogy on achievement among Chemistry students,

revealed that simulations in learning, have significant effects on achievement of students in Chemistry. The findings were also in agreement with the findings of Joel (2017) who established that students achieved satisfactory academic achievement after exposure to virtual learning through PhET interactive simulation.

The findings on the computer simulation as interactive by Kotoka and Kriek (2014) stressed that simulation allows users to interact with it and minimizes abstractness of hazardous Chemistry concept to the students. Students in experimental group were able to visualize, explore and formula scientific explanations in Chemistry that were otherwise impossible to observe and manipulate by students in control group. This implies that computer simulation improves students' achievement when compared with lecture method.

The findings on the students' interest in Chemistry by means of interactive simulations achieved substantial difference in the mean interest scores of students taught Chemistry by the use of PhET interactive simulations and those taught with conventional method. This discovery is in accord with the discovery of Ugur, Abdullahi, Kutalmis and Omer (2017) who concluded that there is an increase in interest of students in the experimental group who were exposed to computer simulations within the 5E teaching model, which is due to the active participation of students in the experimental group in the teaching learning process, the hands-on activities which simplified learning, simulation which made abstract concepts visual and understandable, and the increase in students' interest in using computers in recent years.

The findings on the gender pertaining mean interest scores of students taught Chemistry with PhET interactive simulations pointed out that there was no considerable variation in the mean interest. Also, the finding indicates that gender did not influence students' interest in Chemistry significantly. These findings were in agreement with the findings of Ezeudo and Okeke (2013).

Conclusion

This study revealed that the achievement of Chemistry students in AMAC, FCT- Abuja is independent of gender as significant difference in mean achievement scores between male and female was not found and likewise, the mean interest scores. It was also observed that when PhET interactive simulation package is used, there is significant achievement scores of students in Chemistry than the lecture method. In addition, the use of PhET interactive simulations sustain **students' interest and achievement in any learning activity. It is concluded that PhET interactive simulation is gender sensitive which means that male and female students achieved equally with it.**

Recommendation

Based on the major findings of this study, the following recommendations are proffered:

1. Chemistry teachers should be trained to use PhET interactive simulations in making their lessons interesting, interactive as well as making the students to achieve better.
2. Government and stake holders in education should provide in-service training to chemistry teachers on how to use PhET interactive simulations in teaching.
3. The government should utilize the service of various bodies like the Science Teachers Association of Nigeria (STAN), Nigeria Union of Teachers (NUT), Chemical Society of Nigeria (CSN) and others to organise seminars, workshop and conferences to

inform and train chemistry teachers and other science teachers on the use of PhET interactive simulation in teaching and learning

4. Students should be encouraged to participate in PhET interactive simulation activities because the method provide cooperative and collaborative skills which improve their understanding of chemistry concepts.
5. PhET interactive simulations can be used in other subjects such as Biology, Physics, Health science and Mathematics to test its effectiveness in other subjects.

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