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Effect of using simulation technique in teaching atomic number and atomic structure on students' academic achievement and retention in chemistry

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Abstract
The study focused on the effect of using simulation technique in teaching atomic number and atomic structure on students' academic achievement and retention in chemistry. A pretest, posttest non-equivalent quasi-experimental design was employed. The population of the study was all the Public Senior Secondary School 2 Chemistry students in Obio/Akpor local government area in Rivers State, Nigeria from which 120 students were drawn as the sample size from two of these Schools. One as experimental group and the other as the control group were used in their intact classes. The instrument for the collection of data was Chemistry achievement test (CAT) constructed by the researcher from the topic on atomic number and atomic structure whose reliability index 0.72 was obtained using Cronbach's Alpha. Mean and standard deviation were used to answer the research questions while ANCOVA was used to analyze the hypothesis at 0.05 level of significance. The findings revealed that students in simulation group demonstrated better understanding and retention of the concepts over time. This suggests that the interactive and visual nature of simulation method enhances understanding and long-term memory of the learner. The study concluded that the simulation method is a more effective teaching method for students' achievement and retention in chemistry. Therefore, it was recommended among others that chemistry teachers integrate simulation tools into their instructional practices to foster deeper learning and engagement in chemistry learning. The use of simulation can bridge the gap between theoretical and practical application, thereby stimulating learners to learn and eventually leading to greater success in the learning process.

Keywords: Atomic structure, stimulation, achievement, retention, Chemistry Teaching, Traditional method

Introduction

The science of chemistry deals with matter that is extremely small to view even when under high powered microscope. The microscopic matters are known as atoms that have chemical properties, composition and structures. The atomic structures and other similar concepts of chemistry are difficult for most students to comprehend due to the extremely small size of the particles that make up the matters that are of concern in the studies in chemistry and this has prompted the need to develop ways of teaching and learning of matters just to make understanding of them easy by the chemistry learner. Checchetti *et al* (2015) [4] proposed a type of instructional method that can introduce these concepts following a path way from macroscopic to microscopic and vice versa for students to overcome the difficulties in learning such abstract and complex concepts as the atomic numbers and atomic structures. Hence, the suggestion of a models that can explain these tiny particles in matters and the changes they undergo and this they did by differentiating between macro which is the change of the state of matter and micro meaning the particles that do not change in the number and in the types. The idea of the particle called atom remained obscured for a very long time to scientists. The idea which later originated with the Greek philosophers Leucippus and Democritus about the 5th century B.C but was given no attention until in the early 17th century when it was re-introduced by John Dalton who equally defined atoms as the smallest indivisible particles that make up matters. Though atoms cannot be seen but with this idea given about matter by various scientists including the John Daltons postulate about atoms, it is evident that everything around man is made up of matter and this explains how important these atoms are to man. The particulate nature of matter, their structure, properties and bonding are studied in chemistry by measuring the masses of elements taken part in chemical reactions as Dalton was able to provide direct evidence that matters are made up of atoms. An atom can therefore be defined as the smallest part of an element that has the same properties, composition and structure as the bulk of the matter. The nature and structure of atoms were also discovered by the works of Thomson, Rutherford, Mosley etc., hence, the history of the atoms was traced from Thomson to quantum mechanical model (Netzell, 2015) [14] Scientists such as Rutherford, Mosley etc. further showed experimentally that each atom consist of positively charged protons and neutral neutron making the center of the atom which is the nucleus positively charged while negatively charged electrons orbit at different energy level around the nucleus. Hence, this nature of the atom is associated with Thomson quantum mechanical model as well as the works of other scientists.

One of the essential characteristics of concept learning in chemistry is that every matter is composed of one or more elements which themselves are consist of very tiny particles called atoms. There are more than one hundred elements of which majority are found in nature while few of them are synthesized, this again makes the study of chemistry a complex one that atoms are very small particles that makes up elements that are more than a hundred and that some are natural and others are synthesized. Furthermore, Koehler and Mishra (2009) [11] said that, scientists do not have direct access to most natural phenomena and observation of nature are always filtered through our perspectives and interpreted from within theoretical framework. Meanwhile, others assert that, atoms are extremely small particles and its concept is key component to the whole of learning in chemistry, this seems to have complicated the difficulty students have in learning the chemistry and has led to subsequent construction of many alternative models that will help them learn the concept of the atom (Park & Light, 2019) [15]. Another challenge in the learning of chemistry is the characteristics of macroscopic, microscopic and symbolic context of the atom. Hence, it is important for students to grasp the underpinning concepts of atom in the learning in chemistry and this they need to enable them build up in the learning of the subject. The atomic number and atomic structure had led to learning in chemistry loaded with replicated metaphor, models and theoretical constructs which the scientists use as representations and learning materials in the science of chemistry. Therefore, Atomic simulation models instructional materials should be taken parallel to the study of chemistry education.

Instructional materials are essential to facilitate development of knowledge and acquisition of skills in chemistry as they have the capacity to arouse learners' curiosity, eagerness, and captivate interest and also to attract attention in the learner. Use of instructional materials in teaching and learning in all subject areas is very beneficial to both the learner and the teacher and when they are absent there negative effects are obvious because it makes learning difficult. Ghergulescu *et al* (2019) [7] identified lack of interest in science, technology, engineering and mathematics by students as originated from the perceived difficult nature of the subjects due to abstractness and complexity of concepts learned in these subject areas. Therefore recommended pedagogical approaches for the teaching and learning of science which should include: personalization and modeling such as game-based and computer-based learning that teacher should adopt in the learning (Mawas *et al* 2018 [12]; Muntean *et al* 2018 [13]; Patall *et al* 2018 [16]; Shirazi 2017) [18]. Brigas (2019) [1] recognized that the use of models and simulation for learning had been since ancient times and that model and simulation are useful techniques to studying behavior of phenomena and systems as since of old.

That there are so many tiny particles in matters, which are not possible to see with the naked eye, has also made it that most of the phenomena occurring in nature cannot be easily explained, it is therefore useful to view and explain matters using representations. Model or simulation models are representations of an object or process that describes and explains phenomenon when it cannot be experienced directly. Simulation can be used interchangeable with model but the two are not exactly rhe same. In fact simulation is a type of model but more sophisticated in that in most cases the use of computer and motion is essential. Simulation is the process of creating a model of a real world scenario for a variety of reasons including education, of which the model used, might be real or dramatized but must be carried out in a controlled environment that can permit modification and adjustment of variables. It explains that models are used in simulation and that they are created first before the simulation reason being that it is the model that is used for stimulating the learner to feel the real world scenario. Simulations are used where modeling is difficult such as in meteorology for weather predictions and climate changes but it can be equally used in education context.

Simulation in education context is the re-creation of a real world process in a controlled environment by the teacher for the learner to understand complex concepts. Jones (2017) [10] said, simulations had been in use since 1500 in game of chess which developed to war game and until in the 1950s and 1960s when its recognition in the areas of business and economics and later in social studies, but its use in the public schools was pronouns about the 1950s. Jones (1917) [10] further classified simulation games as social environment simulation whereby students are grouped for the purpose of interaction with one another in a scenario that is governed by rules and that it is intended to teach ethics relating to culture, social, economic and polities for to enable the participant in making decision, useful plans, to solve problems, learn effective communications for everyday living in the 21st century and physical environment simulation in which students do have to function in groups and rules are based on apply what they have learned to the science and nature that is theoretical laws are applied to practical activities. While Umoke and Nwafor (2014) classified simulations as, live, virtual and constructive simulations Brigas (2019) [1], gave two distinct methodologies the teachers needs in using simulation activities which are exploratory mode and expressing mode. He further classified educational simulation models as follows:

- Quantitative models whereby numerical data is used to demonstrate evolution and behavior.
- Qualitative model that may not necessarily depend on the volume of information but can be represented by just a little available data to explain and describe a complex and dynamic system with only the essential characteristics of their structure and behavior.

Brigas (2019) [1] also revealed four ways to identify simulation programs as :

- physical simulation accommodate likely to change some of the variables in a system and to assess the impact on the system behavior.
- in iterative simulation here it is reliable to represent test hypotheses and get results about the phenomenon.
- situational simulation in this situation whereby students engaging in various roles, can gain knowledge about the system in question.
- procedural simulation whereby students going through the process ends up gaining skills to operate certain equipment.

Simulation teaching has emerged as a pedagogical tool in various educational domains, including: healthcare, engineering and in many other educational sectors. In the schools as educators strive to enhance learning outcomes and prepare students for complex challenges, the integration of simulation teaching becomes increasingly pertinent.

Simulation teaching is an experiential practical teaching that offers a active learning outcomes that exceeds traditional methods of teaching. By engrossing the learners in a real scenarios, it enhances several useful skills, stimulates critical thinking, problem-solving, decision making skills, and information literacy skills such that students are able to process and synthesis information through the use of simulation. According to Jeffries (2012) [9], simulation provides opportunities for dynamic involvement, efficient participation, increases students engagement, encourages communication between teacher and students, students to students hence, fosters deeper understanding of concepts, and enriches retention of knowledge which provides the basis for advancement in diverse fields of learning. This active participation approach promotes engagement, enhance mastery of concepts and motivation among students, leading to more effective learning outcomes (Umoke & Nwafor, 2013) [21]

Moreover, simulation teaching can be tailored to cater for various circumstances as well as the specific class environment needs of the learners, it caters for diverse learning styles and preferences. Therefore, educators can direct simulation to cater for various skills levels, learning objectives, ages/class, socio-cultural backgrounds and physical conditions of learners. This ability to change to diverse circumstance ensures inclusivity and equity in education, catering to the needs of students population from different behaviors and backgrounds (Dickmann *et al*,2017).

Furthermore simulation teaching cuts across geographical barriers, enabling remote and distance learning opportunities just as it can be conducted in the physical classroom environment. Technological advancement has positioned virtual simulation so immersive experiences that it can be accessible and useable to the learner anytime anywhere. This flexibility not only enhances accessibility but also facilitates continues learning and at learners convenience which is has given it a hedge over traditional classroom settings. As noted by Cant and Cooper (2010), virtual simulation provides a cost-effective means of training, eliminating logistical constraints associated with physical simulations.

Additionally, simulation teaching fosters reflective practice, encouraging learners to assess their performance, identify areas for improvement, and refine their skills iteratively. By debriefing after simulation session, students gain insights into decision-making processes, enhancing self-awareness and metacognitive abilities (Fanning & Gaba, 2007) [6]. This reflective component promotes life-long learning and professional development, instilling a mindset of continues improvement essential in dynamic, evolving professions.

Furthermore, simulation teaching serves as a bridge between theory and practice, facilitating the application of theoretical knowledge in everyday practices. Simulation teachings enable students to apply what is learned by learners in the classroom and theory to practical situation thereby contextualizing learning within simulation scenarios, whereby students develop a deeper understanding for theoretical concepts and their practical implications (Cant, 2011) [2]. This combination enhances the relevance and applicability of education, preparing students to tackle complex challenges and uncertainties in their respective fields.

Moreover, simulation teaching enables the exploration of high-risk, low-frequency scenarios that may be challenging to replicate in real-life settings. By simulating rare but real-life events whereby students are made to play certain roles, learners can develop competence and confidence in managing such situations without exposure to dangers and risk associated with the real-world which in some instances such as traveling to the moon or space or viewing millions of extremely small particles in matter cannot reach (Ziv *et al*, 2013) [23]. This approach to learning affords learner the opportunity to learn about things that may not accessible, risky and are expensive for the learner.

Furthermore, simulation teachings are activity-based so promotes hands-on, evidence-based practice by promoting opportunities for experimentation and hypothesis testing in a controlled environment. By manipulating variables and observing outcomes, students can gain insights into cause and effect relationships, fostering a scientific mindset and inquiring-based learning (Issenberg *et al*, 2015) [8]. This activity approach imbibes in the learning scientific skills such as critical thinking and problem-solving skills, evidence-informed decision-making which are befitting to developing professional ethics of the scientists.

Additionally, simulation encourages collaboration and teamwork, reflecting the collaborative nature of real-world profession essential for success in various fields. Simulation teaching supports interdisciplinary collaboration, bringing together learners from different fields to address complex, multifaceted problems. By simulating interdisciplinary scenarios, such as healthcare team responding to public health crises or engineers collaborating on sustainable infrastructure projects, students gain exposure to diverse perspectives and develop interdisciplinary communication skills (Brigas, 2019) [1]. This holistic approach prepares future professionals to work collaboratively across disciplines, fostering innovation and synergy in problem solving. Simulation teaching holds immense potential to revolutionize educational practices across diverse domains. It's dynamic. Immersive and adaptive nature caters for the needs of modern learners, promoting active engagement, critical thinking and interdisciplinary collaboration.

Despite the potentials of simulation teaching, there are some difficulties associated with its utilization by teachers. According to Umoke and Nwafor (2013) [21], some challenges with the use of simulating teaching are as follows:

- Time factor, such as time needed for the preparation as well as the time for individual learner to learn at his pace which may require extra time or even time outside the regular class and school timetable may pose a problem.
- The financial status of most of the teachers to purchase accessories or tools required for simulation teaching for example computer, projector may not suffice to the cost of these facilities.
- Difficulty could also be seen in the nature of assessment being that danger and complexity associated in the handling of real-life systems require expertise.

To this Brigas (2019) [1] highlighted the under listed difficulties teachers experience in using simulation including:

- Teachers may not be familiar with or have adequate knowledge of the complexity of the tools and so may not be able to readily use them.
- Model representation is usually based on quantitative modeling and bearing in mind that the basis of the functioning of these systems is only known in part makes its use difficult in educational context.
- There are no readily available methodologies for the use of the simulation activities.

Statement of the Problem

The effectiveness of simulation teaching in enhancing student academic achievement, particularly in the context of atomic structure, is a topic of growing interest and significance in the field of science education. While simulation-based instruction offers interactive and immersive learning experiences, its impact on student achievement warrants systematic investigation why the central concern lies in understanding whether simulation teaching effectively translates into improved academic outcomes for students in terms of their comprehension, retention of knowledge, and problem-solving skills in atomic structure concepts (Chien, 2018) [5].

Furthermore, it is expedient to explore the factors that are determine the relationship between simulation teaching and student academic progress in the teaching-learning process. This includes assessing the role of instructional method, student engagement levels, and the integration of simulations within the broader curriculum. Knowledge about how these factors relate can provide insights into the process through which simulation-based instruction influences students' learning outcomes.

Additionally, discrepancies in the privilege to technological gadgets and differences in instructional practices across various educational stages may influence the effectiveness of simulation teaching on students' academic achievement. Addressing these challenges requires examining the effectiveness of simulation teaching across diverse student populations and educational contexts. By identifying potential barriers and facilitating best practices, educators can optimize the use of simulation teaching to promote equitable academic outcomes for all students (Suits, 2017) [20].

Methodology

The study was carried out to investigate effect of use of simulation method on student's academic achievement and retention in chemistry. The design of the study is quasi-experimental, while the population of the study comprised all SS II Chemistry students in Public Senior Secondary School in Obio/Akpor, Rivers State. By using purposive sampling Two (2) of the public senior Secondary School in Obio/Akpor, Rivers were selected for the study. The data collection instrument, Chemistry achievement Test (CAT) contains two sections (A and B). Section 'A' sought information on the demography data of the students with respect to sex and school name, and class. Section B sought information on students' achievement in Chemistry. The section 'B' consisted of twenty (20) multiple choice questions drawn from drawn from the Chemistry curriculum based on the students level and also from past Chemistry questions generated by Chemistry teachers, using the table of specification. The students were required to choose the correct answers from the options (A-D), listed against each question. In every question, only one option was correct while other options were wrong. The total mark accrued was 20 while the least mark accrued was 0. The reliability coefficient 0.72 was determined using Cronbach Alpha. The chemistry Achievement Test (CAT) was administered to 20 students who were not part of the study samples to generate the reliability index of the instrument. The first week pre-test was given to both experiment and control group. Treatment on simulation was given to the experimental group which was absence in the control. The control group was subjected to conventional teaching methods all these activities lasted for six (6) class session for each group. Mean and standard deviation was used to answer the four research questions posed for the study. While ANCOVA was used to test the three null hypotheses formulated at 0.05 level of significance.

Research Questions

For the purpose of this research the following research questions were stated:

1. What is the mean achievement scores of students taught atomic structure using simulation-based method and those of their counterpart?
2. What is the mean retention scores of students taught atomic structure using simulation-based method and those of their counterpart?
3. What is the mean achievement scores of students taught atomic structure using simulation-based method and those of their counterpart based on gender?
4. What is the mean retention scores of students taught atomic structure using simulation-based method and those of their counterpart based on gender?

Hypotheses

The following hypotheses tested at 0.5 level of significance guided the study:

Ho1: There is no significant difference between mean achievement scores of students taught simulation-based method and those of their counterpart.

Ho2: There is no significant difference between mean achievement scores of students taught simulation-based method and those of their counterpart based on gender.

Ho3: There is no significant difference between mean retention scores of students taught simulation-based method and those of their counterpart.

Ho4: There is no significant difference between mean retention scores of students taught simulation-based method and those of their counterpart based on gender.

Results

Research Question 1: What is the mean achievement score of students taught atomic structure using simulation-based method and those of their counterpart?

Table 1: Mean and standard deviation on academic achievement scores in atomic structure

		Pretest		Posttest		
Group	**N**	**Mean**	**SD**	**Mean**	**SD**	**Mean Gain**
Experimental	15	12.80	2.274	14.87	1.846	2.07
Control	15	12.20	1.612	13.73	2.154	1.53
Total	30	12.30	2.003	14.30	2.054	2.00

Table 1 reveals the pretest and posttest mean and standard deviation on achievement of experimental and control groups as and 12.80±2.274, 14.87±1.846 and 12.20±1.612, 13.73±2.154 respectively with 2.07 mean gain for experimental group and mean gain 1.53control group, showing higher mean gain for the control group.

Research Question 2: What is the mean retention score of students taught atomic structure using simulation-based method and those of their counterpart?

Table 2: mean and standard deviation on retention scores in atomic structure

		Posttest		Retention		
Group	**N**	**Mean**	**SD**	**Mean**	**SD**	**Mean Gain**
Experimental	15	13.73	2.154	17.67	1.799	3.94
Control	15	14.87	1.846	16.87	1.685	2.00
Total	30	14.30	2.054	17.27	1.780	2.97

Table 2 reveals the posttest and retention mean and standard deviation of experimental and control groups as 13.73±2.154, 17.67±1.799 and 14.87±1.846, 16.87±1.685 respectively with 3.94 mean gain for experimental group and mean gain 2.00control group, showing higher retention mean gain for the experimental group.

Research Question 3: What is the mean achievement score of students taught atomic structure using simulation-based method and those of their counterpart based on gender?

Table 3: mean and standard deviation on academic achievement in atomic structure based on gender

		Pretest		Posttest		
Gender	**N**	**Mean**	**SD**	**Mean**	**SD**	**Mean Gain**
Male	15	12.20	2.178	14.00	2.197	1.80
Female	15	12.40	1.882	14.20	1.971	1.80
Total	30	12.30	2.003	14.30	2.054	2.00

Table 3 reveals the pretest and posttest mean and standard deviation on achievement of male and female groups as 12.20±2.178, 14.00.±2.197 and 12.40±1.882, 14.20±1.971 respectively with 1.80 mean gain for male group and mean gain 1.80 female group, showing equality in the achievement mean gain for the both groups.

Research Question 4: What is the mean retention score of students taught atomic structure using simulation-based method and those of their counterpart based on gender?

Table 4: mean and standard deviation on retention in atomic structure based on gender

		Posttest		Retention		
Gender	**N**	**Mean**	**SD**	**Mean**	**SD**	**Mean Gain**
Male	15	14.40	2.197	17.07	1.751	2.67
Female	15	14.20	1.971	17.47	1.807	3.27
Total	30	14.30	2.054	17.27	1.760	2.97

Table 4 reveals the posttest and retention mean and standard deviation of male and female groups as 14.40±2.197, 17.07±1.799 and 14.20±1.971, 17.47±1.807 respectively with 2.67 mean gain for male group and mean gain 3.27 female group, showing higher mean gain retention for the female group.

Hypothesis 1: there is no significant difference between mean achievement score of students taught simulation-based method and those of their counterpart

Table 5: analysis of covariance (ANCOVA) of students mean achievement score based on group

Dependent Variable: posttest					
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	65.266[a]	2	32.633	15.449	.000
Intercept	21.280	1	21.280	10.074	.004
Pretest	55.633	1	55.633	26.337	.000
Group	1.227	1	1.227	.581	.452
Error	57.034	27	2.112		
Total	6257.000	30			
Corrected Total	122.300	29			
a. R Squared = .534 (Adjusted R Squared = .499)					

The result on table 5 shows that p (.452)<0.05 is not significant at 0.05 level of significance. Therefore the null hypotheses which states that there is no significant difference between mean achievement score of students taught simulation-based method and those of their counterpart is retained.

Hypothesis 2: there is no significant difference between mean achievement score of students taught simulation-based method and those of their counterpart based on gender

Table 6: analysis of covariance (ANCOVA) of students mean achievement score based on gender Dependent Variable: posttest

Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Corrected Model	64.951[a]	2	32.476	15.290	.000
Intercept	19.579	1	19.579	9.218	.005
Pretest	64.651	1	64.651	30.438	.000
Gender	.913	1	.913	.430	.518
Error	57.349	27	2.124		
Total	6257.000	30			
Corrected Total	122.300	29			
a. R Squared = .531 (Adjusted R Squared = .496)					

The result on table 6 shows that p (.518)<0.05 is not significant at 0.05 level of significance. Hence, the null hypotheses which states that there is no significant difference between mean achievement scores of students taught simulation-based method and those of their counterpart based on gender is retained.

Hypothesis 3: There is no significant difference between mean retention score of students taught simulation-based method and those of their counterpart

Table 7: analysis of covariance (ANCOVA) of students mean retention score based on group

Dependent Variable: retention					
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	13.003[a]	2	6.501	2.284	.121
Intercept	97.266	1	97.266	34.167	.000
Posttest	8.203	1	8.203	2.881	.101
Group	8.449	1	8.449	2.968	.096
Error	76.864	27	2.847		
Total	9034.000	30			
Corrected Total	89.867	29			
a. R Squared = .145 (Adjusted R Squared = .081)					

The result on table 7 shows that p (.096)<0.05 is not significant at 0.05 level of significance. The null hypotheses which states that there is no significant difference between mean retention score of students taught simulation-based method and those of their counterpart is retained.

Hypothesis 4: There is no significant difference between mean retention score of students taught simulation-based method and those of their counterpart based on gender

Table 8: analysis of covariance (ANCOVA) of students mean retention score based on gender

Dependent Variable: retention					
Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Corrected Model	6.000[a]	2	3.000	.966	.393
Intercept	121.808	1	121.808	39.215	.000
Posttest	4.800	1	4.800	1.545	.224
Gender	1.446	1	1.446	.466	.501
Error	83.866	27	3.106		
Total	9034.000	30			
Corrected Total	89.867	29			
a. R Squared = .067 (Adjusted R Squared = -.002)					

The result on table 8 shows that p (.501)<0.05 is not significant at 0.05 level of significance. Hence, the null hypotheses which states that there is no significant difference between mean retention scores of students taught simulation-based method and those of their counterpart based on gender in retained.

Discussion of Findings

The analysis of the pre-test, post-test, mean achievement and retention data between experimental and control groups provides insights into the effects of the intervention. In the pre-test phase, the control group (Mean = 12.80) performed slightly better than the experimental group (Mean = 12.20), although both groups showed close standard deviations, indicating relatively similar starting points. However, by the post-test phase, both groups improved, with the experimental group maintaining a slightly higher mean score (14.87) than the control group (13.73). Interestingly, in the retention phase, the experimental group showed more improvement (Mean = 17.67) compared to the control group (Mean = 16.87), indicating that the experimental intervention had a positive effect on retention. Research has shown that simulation teaching of atomic structure can significantly enhance students learning outcomes as its improves students' outcomes in comprehension and retention (Chien, 2018) [5].

Gender comparisons reveal that both males and females performed similarly in all phases of the study, with mean scores of 12.20 and 12.40 in the pre-test, 14.40 and 14.20 in the post-test, and 17.07 and 17.47 in retention, respectively. The minor differences in mean scores between males and females, along with similar standard deviations, suggest that gender did not have a significant impact on learning outcomes or retention. This consistency between genders highlights the neutrality of the intervention in terms of gender effects, implying that both male and female participants benefited similarly from the learning experience.

The between-subjects effects analysis on the post-test shows that the pre-test scores significantly predict post-test outcomes (F = 26.337, p = .000), indicating that initial knowledge plays a major role in determining post-test performance. However, the group variable (experimental vs. control) does not significantly affect post-test scores (F = .581, p = .452), meaning the difference between the two groups at this stage was not statistically significant. The model explains 53.4% of the variance in post-test scores (R Squared = .534), with an adjusted R Squared of .499, showing that the model fits the data moderately well. Umoke and Nwafor, (2014) [22], found that simulation facilitates higher academic achievement in Biology than conventional method of teaching. More so, they did not find significant difference in the achievement in male and female students.

Similarly, in the second analysis of post-test effects with gender as a variable, the pre-test again shows a significant influence on post-test results (F = 30.438, p = .000), but gender does not significantly contribute to the post-test performance (F = .430, p = .518). This further reinforces the finding that gender differences in this study do not play a role in the observed outcomes. The overall model explains 53.1% of the variance in post-test scores (R Squared = .531), slightly lower than the group analysis, but still indicative of the importance of pre-test scores. Reddy and Mint (2017) [17] studies the impact of simulation-based education on Biology students' academic achievement and saw that there was slight improvement in learning and cognitive skills of the students as well as significant increase in this improvement between male and female students.

Conclusion

Despite the many potentials of simulation-based teaching method has the potential to enhance students learning especially in the case of atomic structure a very fundamental concepts but equally and abstract and complex one which also is core to the learning and practice in chemistry, students in this research study did demonstration that simulation can actually stimulate both academic performance and retention in students. This is an affirmation to previous studies on simulation method of teaching but that there was no significance between the groups may be attributed to teachers' lack of adequate method in the handling of the experiment or that they are not familiar at all to the method themselves and so are unable to carry out the method effectively as expected otherwise simulation method would have recorded outstanding performance.

More so, that there is no significance between the group that studied using simulation and those of the counterpart in performance may be associated with students' lack of interest and focus in learning. Secondly, unpreparedness to learning especially when new ways of learning is introduced may have equally contributed immensely to the results so farfetched which is also below expectation.

Recommendation

It was recommended that:

1. Chemistry teachers gain adequate knowledge of using simulation-based method of teaching before embarking on it for teaching especially for abstract topics such as atomic structure.
2. Chemistry teachers use models that their operation is familiar and that well represent the real-objects or scenario describe so as not to confuse the students

further in learning of abstract concepts in science but rather to help capture the interest of the students for proper preparedness for the learning intended.

3. Chemistry teachers should assess properly the level of students understanding as in previous knowledge in the subject before going onto more complex learning concepts such as the atoms and their structures and they should also use of such materials for learning as its adequate for the level and type of learners.

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