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THE EFFECT OF COMPUTER SIMULATION ON STUDENT PERFORMANCE IN HIGH SCHOOL CHEMISTRY LEARNING ON CHEMICAL EQUATIONS

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ABSTRACT

Chemical equations have been identified as a complicated topic in the Nigerian School Certificate. This study investigates the effect of computer simulations on student performance in high school chemistry courses on the topic of chemical equations in Offa, Nigeria. This study adopted a quasi-experimental research design with a pre-test, post-test, and non-randomized control group. The population is all high school students totaling 756 students. The sample was selected purposively, namely 136 students. Chemical Equation Performance Test (CEPT), Online Computer Simulation of Chemical Equations (OCSCE), and Cognitive Force Checklist (CSC) with reliability coefficients of 0.76, 0.81, and 0.78, respectively, were used as instruments for the study. The results of this study are that there are differences in the performance of students who are taught using computer simulations, between the performance of male and female students, and differences in performance between students who score low, medium, and high. It was concluded that computer simulation affected the performance of high school students. It was supposed that computer simulation affected the performance of high school students. It is recommended that future researchers apply computer simulations to other learning.

PENGARUH SIMULASI KOMPUTER TERHADAP KINERJA SISWA DALAM PEMBELAJARAN KIMIA SMA PADA TOPIK PERSAMAAN KIMIA

Kata Kunci:

Persamaan kimia
Gaya kognitif
Simulasi komputer
Kimia SMA
Kinerja siswa

ABSTRAK

Persamaan kimia telah diidentifikasi sebagai salah satu topik sulit dalam Sertifikat Sekolah Nigeria. Penelitian ini menyelidiki efek simulasi komputer terhadap kinerja siswa dalam pembelajaran kimia sekolah menengah atas pada topik persamaan kimia di Offa, Nigeria. Penelitian ini mengadopsi desain penelitian kuasi-eksperimental kelompok kontrol pre-test, post-test, non-randomized. Populasinya adalah semua siswa SMA berjumlah 756 siswa. Sampel dipilih secara purposive, yaitu 136 siswa. Uji Kinerja Persamaan Kimia (CEPT), Simulasi Komputer Online tentang Persamaan Kimia (OCSCE) dan Daftar Periksa Gaya Kognitif (CSC) dengan koefisien reliabilitas masing-masing 0,76, 0,81, dan 0,78, digunakan sebagai instrumen untuk penelitian. Hasil penelitian ini yaitu terdapat perbedaan kinerja siswa yang diajar menggunakan simulasi komputer, terdapat perbedaan antara kinerja siswa laki-laki dan perempuan, dan terdapat perbedaan kinerja antara siswa yang mendapat nilai rendah, sedang, dan tinggi. Disimpulkan bahwa simulasi komputer berpengaruh terhadap kinerja siswa SMA. Direkomendasikan kepada peneliti selanjutnya untuk dapat menerapkan simulasi komputer pada pembelajaran lainnya.

1. INTRODUCTION

Chemistry is an essential subject for the advancement of science and technology. Its application in medicine, engineering, manufacturing, food production, and processing, among others, is unquantifiable. Chemistry is one of the main branches of science; it involves the study of the composition, properties, and uses of matter and the changes that matter undergoes. At the secondary education level, Chemistry is a compulsory subject for any student interested in pursuing science and technology-based courses in tertiary institutions. Hence, the importance of the subject cannot be overemphasized as its knowledge not only facilitate the provision of our basic needs but also helps to improve the quality of human life [1].

Despite the importance of the knowledge of Chemistry for human development, Nigerian students' performance in the subject has not been consistently satisfactory in both internal and external examinations [2], [3]. Some of the reasons, as reported by researchers, for students' poor performance in Chemistry include the deployment of poor instructional strategies and the abstract nature of Chemistry concepts [3]-[6], inadequate number of qualified teachers, shortage of laboratory facilities, poor physical infrastructure, non-availability of instructional materials, and their inappropriate use [7]. High school and university students in many nations in the world struggle to learn Chemistry due to teachers' inappropriate strategies [8].

Statistics from May/June 2014-2019 West African Senior School Certificate Examinations (WASSCE) conducted by the West African Examinations Council (WAEC) indicate inconsistencies in the performance of candidates in Chemistry (Figure 1). Figure 1 also displays the students' Biology, Chemistry, and Physics results from 2014-2019 at the credit pass.

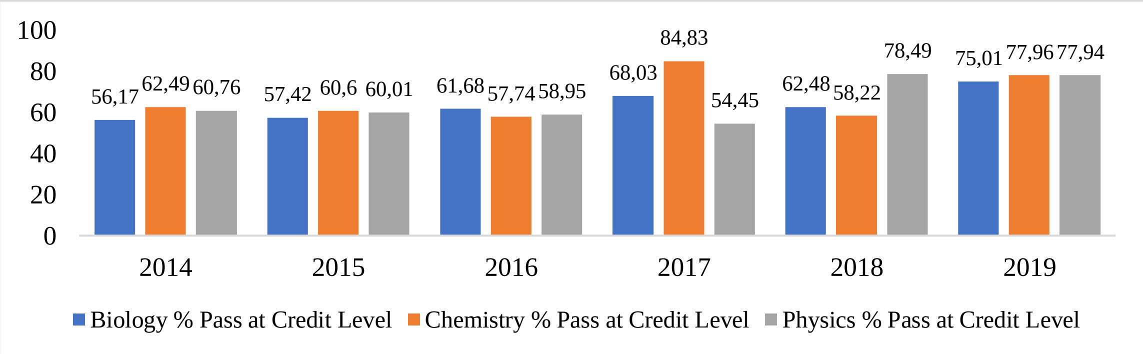

Figure 1. Chart of Students' Results in the West African Senior School Certificate Examinations in May/June for Biology, Chemistry, and Physics in Nigeria (2014-2019)

Chemical equations are symbolic and shorthand representations of the changes that occur in chemical reactions. This concept of chemical equations runs through the length and breadth of the subject, meaning that there is hardly any aspect of Chemistry in which one does not come across chemical equations. A chemical equation is a universal language of Chemistry worldwide, irrespective of each nation's language. Once a student is deficient and unskilled in balancing chemical equations, he will not be able to understand other topics such as stoichiometry, mole ratio, calculation of molar mass from their reacting mass depicted by the chemical equation, electrochemistry, redox reaction, practical Chemistry, etc. [9]. The knowledge of writing and balancing chemical equations is expected to scaffold chemistry's theory and practical content.

The focus of this study on chemical equations as a topic was premised on the Chief Examiner's reports of the West African Examinations Council 2014-2019, which consistently identified chemical equations as one of the topics that posed difficulty for the candidates in the examinations. The reports stated clearly that the candidates had a poor understanding of the general principles of writing chemical formulas and balanced equations, amongst others. The implication of the inconsistencies in candidates' performance in Chemistry and other science disciplines is that many students may not be able to secure admission into science-based courses in higher institutions of learning, and those who manage to secure admission may find it difficult to cope with advanced studies in science disciplines.

Students' difficulties in understanding Chemistry concepts are traceable to traditional teaching strategies adopted by the teachers [5]. The conventional method popularly used by teachers in science and technology education had produced some learners who can explain learned scientific concepts verbally but cannot convert such knowledge into technologies that could practically proffer solutions to human challenges [10]. The labor market is already congested with many such verbalizers and visualizers who are again being recycled to become ineffective teachers or unemployable or ineffective [11]. Hence, alternative and innovative strategies have been proposed to make Chemistry more attractive to students [5]. This need to find alternative strategies for teaching the subject necessitates the incorporation of Information and Communication Technology (ICT) into the teaching and learning of Chemistry to enhance meaningful learning of the subject.

The use of interactive CD-ROMs, multimedia software applications, audio/visuals, and multimedia presentations is known as Computer-Assisted instruction (CAI) [11]. CAI allows learners better access to varieties of instructional materials, keeps a record of learning experiences and progress, and provides feedback on learners' weaknesses and strengths [12]. Furthermore, CAI can help students conduct laboratory experiments that are not easy to conduct physically, thus enabling them to learn systematically within a shorter period. Hence, several computer applications and software programs can be used to teach a subject matter. An example of such a computer applications is a simulation [13].

Simulation is a software program that represents events that occur in real life in a controlled environment. Computer simulations (CS) are better than dynamic visualizations known as animations and are also different from the diagram in a textbook which is static because they allow user interaction [12]. Computer simulation is a tool that can help learners understand complex concepts in Chemistry [5]. He also described computer simulation as a model designed to represent or imitate a theory, real concept, or process whereby the learner can input data and obtain results.

The use of computer simulation for science teaching has the potential to enhance better learning outcomes in unprecedented ways. Computer simulations helped improve conventional classroom methods by helping learners to view processes and events that were previously invisible to become visible [14], [15]. In a study involving 115 senior class III Ugandan learners, gathering data using Exemplar Achievement Test, ANCOVA, and Mann-Whitney U-test revealed that students knew very little about chemical bonding. It was further revealed that students exposed to computer simulation combined with hands-on laboratory activities had considerably better achievements than others [16].

Similarly, another study studied how computer-based simulations could affect high school students' Chemistry achievement in Kenya. The study, carried out in four co-educational schools in Nakuru East Sub-county, involved 175 students [17]. ANOVA and ANCOVA analysis revealed that computer-based simulations significantly contributed to comprehending chemistry topics and principles more than the regular teaching method. Other studies have also explored the possible effect of computer simulations on senior school students' Chemistry achievement [18]. There were 78 (34 boys and 44 girls) SSSII pupils from two co-educational secondary schools in Anambra State's Awka Education Zone in the sample. Data were obtained using Chemistry Achievement Test and analyzed using mean gain and ANCOVA. The result revealed that students taught Chemistry using computer simulation achieved better results than those taught using the lecture method.

Olorukooba et al. also investigated the effect of computer simulation packages on secondary school Chemistry students' performance [4]. One hundred Senior Secondary School II (SSII) Chemistry students were randomly sampled from Zaria Education Zone, Kaduna State, Nigeria. A Qualitative Analysis Performance Test (QAPT) was used for data gathering. The results obtained using t-test statistics revealed better achievement in Chemistry by students taught using computer simulations compared to those taught using traditional methods. The study further revealed no gender influence when computer simulations were used to teach Chemistry. Plass et al. investigated how effective computer simulations were in Chemistry learning[12]. The study involving 718 High School students was carried out in 25 schools in rural (Texas) and urban (New York) settings. The study found that computer simulations improved students' comprehension and knowledge transfer. Udo and Etiubon compared the effectiveness of chemistry simulations, guided discovery, and traditional expository instructional methods on the achievement of secondary school students in Chemistry [19]. The ANCOVA analysis revealed that the use of chemistry simulations produced better student achievement in Chemistry than the traditional expository method and that the output for the Chemistry simulations and the guided discovery methods were similar.

There three types of representations have been identified in the learning of Chemistry [21]-[22]: macroscopic (observable with our sense organs), submicroscopic (non-observable with our sense organs), and symbolic (symbols, chemical formulae, chemical equations). These authors opined that students' performance in Chemistry depends on their understanding of the three levels of representations, also referred to as multiple representations. Computer technology like computer simulations, images, molecular models, and computer animations would assist in implementing and linking the three types of representations for a comprehensive understanding of Chemistry concepts [22]. Computer simulations can be an effective strategy in learning chemical equations as it does not only help in writing and balancing chemical equations but also helps in linking and bridging the gap among the three types of representations while providing instant feedback to the learners.

Several studies have indicated that gender, score level, and cognitive styles influence students' performance in Chemistry. However, there are contradictory reports on the directions of the influence. Gender can be viewed as features, behaviors, roles, and expectations (femininity and masculinity) that society assigns to the two sexes on a different foundation [23]. It is a social determinant that varies from one society or culture.

The issue of students' gender has continued to resonate in science education research considering the number of studies that have given it attention. For example, studies indicate significant gender differences concerning students' achievement in Chemistry in favor of male students [24], [25]. However, other studies show no significant gender influence in science achievement [26]. Also, another Chemistry study revealed that students' performance in Chemistry using computer simulations is not gendered-specific [4], [16], [18], [23]. As a result, it is thought appropriate to evaluate the impact of gender on the Chemistry performance of students when exposed to computer simulations.

The student's score level is equally worth investigating as it affects their performance in science subjects. Score level is a ranking model used in educational research as a variable to classify students as high, medium, or low based on their test scores. Gambari and Yusuf [27] categorized students into high, medium, and low scorers based on their performance when assigned an academic task. They opined that the high scorers tend to be more intelligent than the medium and low scorers but that the medium and low scorers can also perform in academic activities that do not require high cognitive skills.

Researchers have come up with diversified views on the influence of students' score levels on their performance in science in Nigeria. According to Alabi, there was no significant difference in student achievement depending on score levels using logical prose, idea map format, and concept map structure [28]. Gambari et al. [29] and Olarewaju [30], in a study on virtual laboratory and WebQuest, also found no significant difference in performance among high, medium, and low scorers in Chemistry classes. However, a study found a significant difference in performance among low, medium, and scorers in Chemistry when using the mastery learning strategy [3], while another study found that low scorers performed better when using WebQuest [31]. Lawal [32] also discovered that when low, medium and high-scoring senior school students were taught utilizing the learning together technique and Jigsaw learning, there was a substantial difference in their accomplishments in favor of the high scorers.

Students have individual ways of acquiring and using knowledge which has to do with their learning style. Cognitive style is an individual learner's way of perceiving, organizing, processing, and recalling information from the environment. It is used synonymously with learning styles and differs from individuals' abilities. There are different dimensions of cognitive styles. Some of them are: analytic and global, holist and serialist, visual, auditory and kinesthetic, and field-dependent and field-independent [33]. Due to the student-centered nature of this study, the field-dependence and field-independence cognitive style designed by [34] was adopted.

Some of the results of related studies on cognitive styles showed that students' cognitive styles had no significant influence on their achievement [35], [36]. Conversely, some research found a significant difference in the achievement of students based on their cognitive styles [37]-[40]. These differences in learning styles may account for the variations in students' understanding of the concept. Hence, this may be the source of students' poor performance or difficulty learning science and chemistry**.** Hence, the influence of the variable of cognitive style was also investigated in this study. What is novel about this study is that none of the studies reviewed focused on chemical equations as a topic despite the overwhelming influence on students' understanding of other topics. None of them also examined a combination of gender, score levels, and students' cognitive styles as moderating variables, as done in the current study. These are the gaps the study sought to fill.

The framework for computer simulations is based on Mayer's [41] constructivism theory of learning and is heavily anchored in the cognitive theory of multimedia learning. The theory states that people learn more deeply from words and pictures than from words alone. In multimedia learning, learners have a deeper understanding of the content as they learn from words and motion pictures rather than from words alone. Learners are also able to construct their knowledge. Concerning multimedia learning, this theory advances three main assumptions: There are two separate channels (auditory and visual) for processing information (sometimes referred to as Dual-Coding theory), each channel has a limited (finite) capacity (similar to Sweller's notion of Cognitive Load), and learning is an active process of filtering, selecting, organizing, and integrating information based upon prior knowledge [41]. Information in the form of pictures, words, and sound waves are not interpreted in a mutually exclusive manner; instead, they are selected and o dynamically organized to produce rational mental constructs. Learning is a product of integrating prior knowledge with new pieces of information [41].

Constructivism is about how learning takes place, especially active learning or learning by doing. Social constructivists, emphasize that learning occurs socially through a process in which knowledge is first constructed before being appropriated [42]. Constructivists posit that meaningful learning occurs with the active involvement of individuals, which enables them to gain confidence and motivation to engage in more tasking experiments. Piaget (1896-1980), Vygotsky (1896-1934), and Bruner (1915-2016) are all proponents of the theory of constructivism, which is on how learners internalize knowledge. Learners create new knowledge from past experiences through adaptation and assimilation. Constructivism advocates hands-on, practical-based learning processes that facilitate the development of proper frames of thought for authentic learning.

Studies on the use of computer simulations and a constructivist approach to conceptual understanding in physics exemplified that computer simulation is founded on constructivism theory since it uses the 5-E learning cycle to assist scientific inquiry [43]. The 5-E learning cycle are engaging, exploring, explaining, elaborating, and evaluating, which are the five learning cycle stages.

The computer simulation complements Gagne's nine levels of learning model on constructivism [44] itemized Gagne's nine levels as: gaining attention, promoting the memory of earlier knowledge, stimulating recall of prior knowledge, educating learners of the goal, providing learning guidance, eliciting performance, providing feedback, assessing performance, and enhancing retention and transfer [43]. Computer simulation utilizes video, sound animation, text, and graphics to gain students' attention for easier comprehension and better performance, i.e., applying Gagne's first levels of learning.

Computer simulation makes learners fully aware of the lesson's objectives, making it possible to monitor students' experiences at the second level of learning. Furthermore, it helps learners to recall information and solve problems that motivate the recall of prior knowledge of the content area. Presenting stimulus, the fourth level, can be tasks on chemical equations for students to balance. The computer simulation utilized in this study provides guidance on which steps or buttons to press to balance chemical equations. Computer simulation builds confidence in the students by enhancing their performance as it helps them to graduate from one level of difficulty to another through providing feedback and positive reinforcement from the exercise on chemical equations. It also enhances the retention and transfer of knowledge gained during the lessons. The theories identified reflect the theoretical and applied model in teaching and learning and serve as the theoretical bases of computer simulation [44].

To guide this study, the following research questions were generated: (1) what is the difference in the performance of students taught chemical equations using computer simulations and those who were not?, (2) is there a difference in the performance of male and female students taught chemical equations using computer simulations?, is there a difference in the performance of students taught using computer simulations based on their score levels?, and is there a difference in the performance of students taught chemical equations using computer simulations based on their cognitive styles?

2. METHOD

The flow chart for this research is presented in Figure 2. The detail of the methodology is explained after that.

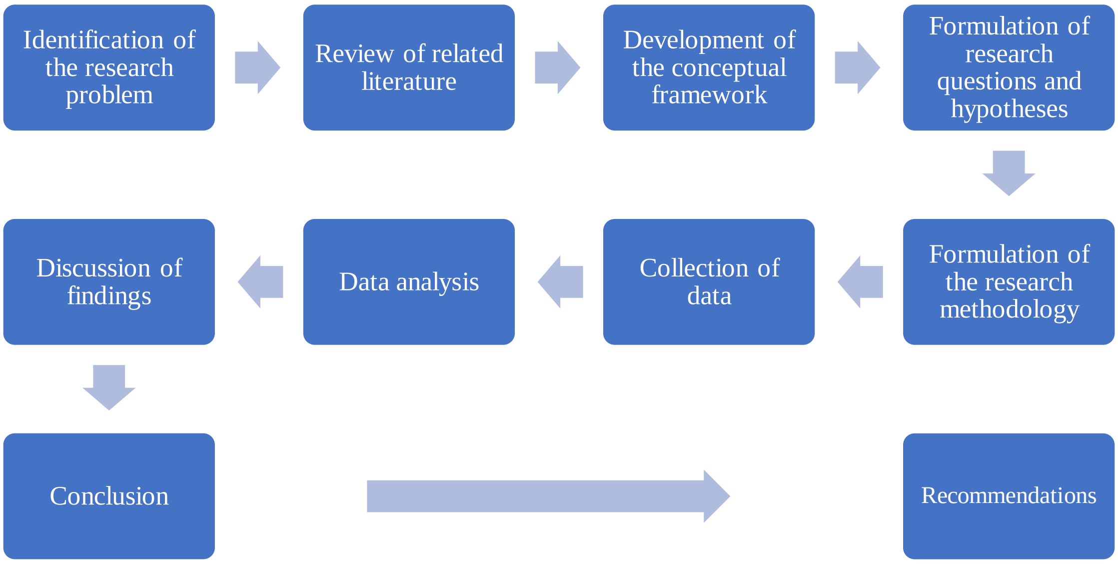

Figure 2. Research flow chart

The study adopted a quasi-experimental design with a pre-test, post-test, and non-randomized control group. A 2×2×3×2 factorial research design was employed, and it represented two groups of instructional strategies (computer simulation instructions and conventional instruction), students' gender (male and female), three categories of score levels (low, medium, and high) and two groups of cognitive styles (field-dependent and field-independent) respectively. The computer simulations and conventional instruction for experimental and control groups made up the independent variable. The dependent variable was the students' performance, while the moderating variables were students' gender, score levels, and cognitive styles. The design used is shown in Table 1.

Table 1. Design for the Study

Group	Pre-test	Treatment	Post-test
Experimental Group	O_1	X	O_2
Control Group	O_3		O_4

Where:

O_1 : pre-test for the experimental group
O_2 : posttest for the experimental group
X : treatment using computer simulations for the experimental group
O_3 : pre-test for the control group
O_4 : posttest for the control group

The participants in this study were all senior secondary school students in Offa, Kwara State, Nigeria. The target population was 756 senior secondary school II (SSS1I) students offering Chemistry. 136 students in two intact classes were drawn from two co-educational senior schools in the study area as samples. The two schools were purposively selected based on the presence of functional computer laboratories. The two schools were randomly assigned to experimental and control groups. In addition, the Chemistry students were grouped into the two categories of cognitive styles (field-dependent and field-independent) using scores obtained from an earlier Cognitive Style Checklist administration developed by Wyss [44].

The following null hypotheses were formulated and tested at a .05 significant level.

HO_1: There is no significant difference in the performance of students taught chemical equations using computer simulations and those who were not.

HO_2: There is no significant difference in the performance of male and female students taught chemical equations using computer simulations.

HO_3: There is no significant difference in the performance of students taught chemical equations using computer simulations based on their score levels.

HO_4: There is no significant difference in the performance of students taught chemical equations using computer simulations based on their cognitive styles.

The study made use of three research instruments. They are: Chemical Equations Performance Test (CEPT), Online Computer Simulations on Chemical Equations (OCSCE), and Cognitive Style Checklist (CSC). The Chemical Equations Performance Test (CEPT) was a researcher-made test for data gathering. The CEPT was divided into two sections, A and B. Section A requested the biodata of the respondents, while section B consisted of 30 multiple-choice test questions on Chemical Equations. Each question had four possible answers (A-D), one of which was right.

CEPT was used to determine the pre-treatment and post-treatment knowledge of the students on the chemical equation. The instructional tool (Treatment) that was used to teach the students about Chemical Equations in the experimental group was the Online Computer Simulations on Chemical Equations (OCSCE). The OCSCE is an adapted version of the Interactive Simulations designed by Physics Education Technology [45], Balancing Chemical Equations in 5 basic steps [46], [47] (Figure 3).

Figure 3. Screenshot of Computer Simulations on Chemical Equations [38]

The Cognitive Style Checklist (CSC), was used to categorize the students into field-dependent or field-independent, and it consisted of statements that best described each participant in terms of their cognitive styles by asking them to indicate the statements in the checklist that applied to them [34]. Lastly, the Teachers Training Manual on Computer Simulations (TTMCS) prepared by the researchers was used to train the research assistants on how to use the Online Computer Simulations on Chemical Equations for the treatment. Lesson plans were prepared for each of the five periods taught to the experimental and control groups.

The three instruments were taken through the face and content validities by referring them to three Chemistry instructors from three secondary schools in Offa, Nigeria, and two academics each from the Department of Science Education and Department of Chemistry at the University of Ilorin, Nigeria. They were given a validation form, and the purpose was to check the relevance, comprehension, content coverage, application, language, and suitability of the instruments. Their ratings and assessments were then used in fashioning out the final draft of the study.

Furthermore, the content validity of CEPT was established by preparing a table of specifications in which each of the questions was assigned to any of Bloom's taxonomy lower-order cognitive skills, namely knowledge, comprehension, and application. After that, the reliability of CEPT as a test item was determined through a test re-test method of three weeks intervals by administering it to students in an intact class in a school in Offa, which was not involved in the main study but still within the same population. Using the Pearson Product Moment Correlation Coefficient, a reliability coefficient of 0.76 was obtained.

The researchers obtained permission from the school Principals and Heads of the Science Department to conduct the study in their schools. A consent form was also administered to the Chemistry teachers in the sampled schools to solicit their involvement as research assistants. The Chemistry teachers in the two schools served as research assistants, and a day was used to train the teacher in the experimental school on how to use the Online Computer Simulations on Chemical Equations. The Chemistry teachers aided the researchers with the pre-test and post-test administration.

Before subjecting the students to treatment, they were informed about the study's objectives and the research aims. As part of the ethical consideration guarding the conduct of research, the students were given an informed consent form to sign, indicating their willingness to participate in the study and their freedom to do so, signed by their parents/guardians. The students were given CEPT as a pre-test to determine their prior knowledge of Chemical Equations. The score from the pre-test was used to place the students into score levels.

The students who scored 21-30 marks (70% and above) out of a total of 30 marks were categorized as High Scorers, those who scored 12-20 marks, that is (40-69%) were categorized as Medium Scorers while the Low Scorers were those who scored 1-11 marks which is (0-39%). Also, the Cognitive Style Checklist was administered to them to classify them into field-dependent and field-independent students.

A total of five periods of lessons, each lasting forty minutes, were conducted in two weeks for each of the two groups. The Chemistry teacher in the school used for the experimental group served as the research assistant who taught the experimental group after receiving the appropriate training on using the use of the OCSCE lesson plan for the experimental group. The teacher took the students through the five simple steps highlighted for balancing chemical equations by Bresyln Wayne https://www.youtube.com/watch?v=zmdxMlb88Fs as follows using the OCSCE.

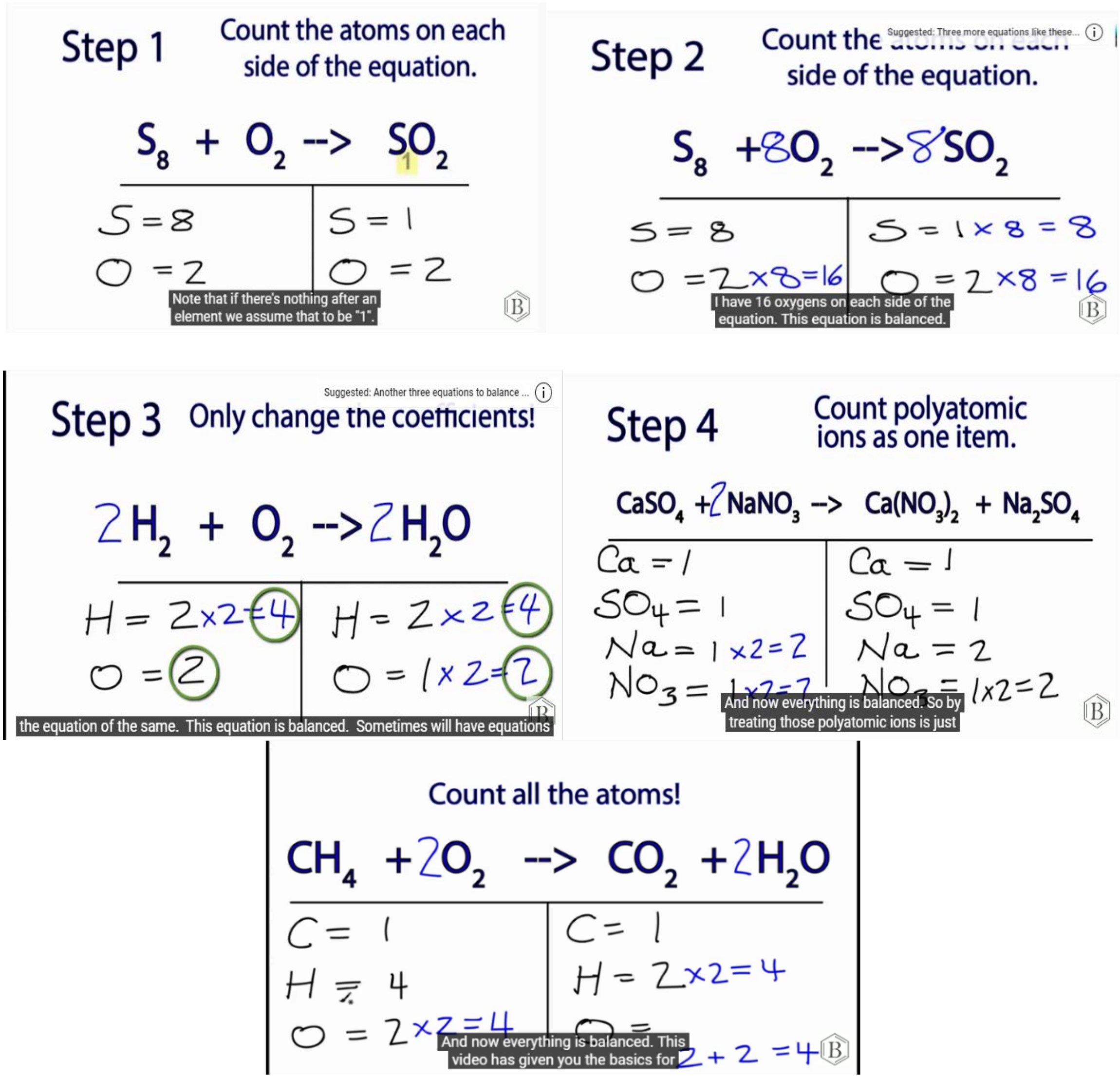

Figure 4. Five Steps for Balancing Chemical Equations by Bresyln Wayne

Each of the steps was crucial to getting a balanced chemical equation. The students' performances were affected by any mistake in any of the steps. Once a student got one of the steps wrong, the chemical equation would be wrong.

In the control school, the chemistry teacher taught participating students chemical equations conventionally and did not use simulations. The CEPT earlier administered as a pre-test was reshuffled and administered as a post-test to both groups to determine the students' performance. The researcher then scored the post-test. To avoid disrupting school activities, the pre-test, treatment, and post-test took place during the periods designated for Chemistry on the school's timetable.

3. RESULTS AND DISCUSSION

Figure 5 shows an example of a screenshot of a student in the experimental group during the learning process. This particular screenshot indicates that the student could follow the steps earlier highlighted by the teacher, and he could eventually balance the equation. This correctness was widespread among the experimental group students, which is why they performed significantly better than their counterparts in the control group, who had no opportunity of experiencing the OCSCE.

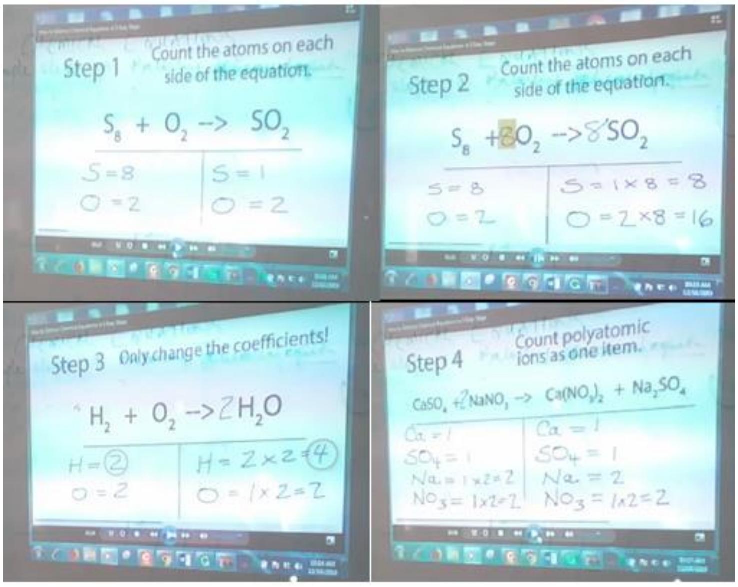

Figure 5. Screenshots of Students' Work

Research Question 1: What is the difference in the performance of students taught chemical equations using computer simulations and those who were not?
Research Hypothesis 1: There is no significant difference in the performance of students taught chemical equations using computer simulations and those who were not.

Table 2. The t-test Examination of the Significant Differences in the Performance Between the Experimental and Control Groups

Groups	N	Mean gain score	SD	df	T	Sig. (2-tailed)
Experimental	52	8.86	3.69	134	-5.05	0.00
Control	84	1.59	4.24			

P < 0.05

Table 2 shows the results of the data analysis for research question 1 and hypothesis 1. The mean gain score of the experimental group 8.86 is greater than that of the control group meaning that the experimental group benefitted more from learning using the computer simulations than the control group. So also, the t-value (t (134) = -5.05, p<0.05) obtained from the hypothesis testing was significant at the .05 alpha level. This suggests a significant difference in the performance of the experimental and control groups in favor of the experimental group. As a result, hypothesis 1 was rejected, implying that computer simulations improved students' performance in chemical equations.

This result revealed that the students in the experimental group performed much better than the control group. This difference is traceable to the use of computer simulations which might have made the experimental group more involved in learning, thus, making them perform better without any difficulty. Students who were taught with computer simulations achieved better scores than those taught without them [4], [12], [16]-[19]. So also this result correlates with the postulation of constructivism and the cognitive theory of multimedia learning, as earlier expressed in this manuscript.

Research Question 2: Is there a difference in the performance of male and female students taught chemical equations using computer simulations?
Research Hypothesis 2: There is no significant difference in the performance of male and female students taught chemical equations using computer simulations.

Table 3 compares the performance of male and female students taught using simulations. The males and the females had pre-test mean scores of 10.70 and 9.48, respectively, whereas their post-test mean scores were 19.87 and 15.66, respectively. Also, the male and female groups' mean gain scores were 9.17 and 6.18, respectively. The mean gain scores of the males and the females were 9.17 and 6.18, respectively. The mean gain scores of the males were higher than that of the females by 2.99.

Table 3. Mean Gain Scores of Male and Female Students' Performance in Chemical Equations Taught Using Computer Simulations

Gender	N	Pretest		Posttest		Mean Gain Score
		M (X)	SD	M (X)	SD	
Male	23	10.70	4.18	19.87	6.39	9.17
Female	29	9.48	3.21	15.66	4.89	6.18

Furthermore, Table 4 presents the t-test analysis of significant differences in male and female students' performance in the experimental group. So also, the t-value (t (50) = -2.44, p<.05) was statistically significant at the .05 alpha level. This finding reveals a significant difference in the performance of male and female students who were taught chemical equations using computer simulations, with the male students outperforming the female students. As a result, hypothesis 2 was rejected, implying a significant difference between the performance of males and females when taught chemical equations using simulations in favor of the males.

Table 4. t-test Analysis of Significant Differences in Male and Female Students' Performance in the Experimental Group.

Gender	N	Mean Gain Score	SD	df	t	Sig. (2tailed)
Male	23	9.17	5.26	50	-2.44	0.02
Female	29	6.18	3.86			

P < .05

Perhaps, the features in the computer simulations appealed more to the male students making them versatile and motivated, which probably might have helped them to solve the task easily and meaningfully. This finding is consistent with that of Dantani [24], who found a significant difference in male and female students' achievement when concept mapping (CACM) and digital video instruction (DVI) were used. It is also similar to Yusuf and Afolabi [25], who found a significant difference in male and female students' achievement when play simulation was used. On the other hand, the result contradicts the findings of John, et al [16], who found no significant difference in the achievement between boys and girls taught via computer simulation. Furthermore, the outcome differed from those of Okwudiba, et al [18], who discovered that there was no substantial difference in male and female pupils' achievement when taught with chemistry simulations.

Research Question 3: Is there a difference in the performance of students taught using computer simulations based on their score levels?

Research Hypothesis 3: There is no significant difference in the performance of students taught chemical equations using computer simulations based on their score levels.

Table 5 presents the performance of low, medium, and high scorer students taught chemical equations in the experimental group. The mean gain scores for low, medium and high scorers were 1.19, 1.92, and 6.77, respectively. The mean gain score of the high scorers was higher than that of the medium and low scorers. This means that the high scorers benefitted most from teaching chemical equations using computer simulations, followed by the medium and low scores.

Table 5. Mean Gain Score of Low, Medium, and High Scorers in the Experimental Group

Caterogy	Pre-test Mean	Post-test Mean	Mean gain score
Low	7.79	9.78	1.19
Medium	14.22	16.14	1.92
High	16.81	23.58	6.77

ANCOVA was used to analyze the data obtained for hypothesis 3 (Table 6). As indicated in the table, the F-value (F (2,48) = 35.68, p<0.05) was significant because the p-value of 0.00 is less than the .05 alpha level. Hypothesis 3 is therefore rejected, meaning there was a significant difference in the performance of students taught using computer simulations based on their score levels.

Table 6. Summary of the Analysis of Covariance of Significant Differences in Students' Performance in the Experimental Group for Low, Medium, and High Scorers

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1398.57[a]	3	466.19	56.17	.00
Intercept	768.42	1	768.42	92.58	.00
Pre-Test	6.45	1	6.45	.777	.38
Score Levels	592.30	2	296.15	35.68	.00
Error	398.41	48	8.30		
Total	17757.00	52			
Corrected Total	1796.98	51			

a. R Squared = .778 (Adjusted R Squared = .764)

Further analysis was carried out using Bonferroni's post hoc analysis of means comparison (Table 7) to determine where the differences are. The results showed differences between high and medium scorers, high and low scorers, and medium and low scorers, with the mean gain difference of 12.83, 6.82, and 6.01, respectively.

Table 7. Bonferroni Post-hoc Analysis of the ANCOVA of the Mean Difference of Low, Medium, and High Scorers Students

(I) Score Levels Posttest Experimental	(J) Score Levels Posttest Experimental	Mean Difference (I-J)	Std. Error	Sig. [b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Low	Medium	-6.01*	1.121	.000	-8.788	-3.227
	High	-12.83*	1.520	.000	-16.599	-9.059
Medium	Low	6.01*	1.121	.000	3.227	8.788
	High	-6.82*	1.145	.000	-9.662	-3.981
High	Low	12.83*	1.520	.000	9.059	16.599
	Medium	6.82*	1.145	.000	3.981	9.662

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

These results indicate that computer simulation had a better effect on student's performance in the experimental group among the three scoring levels (low, medium, and high scorers students) in favor of the high-scoring students. Thus, the high scorers' students performed well, while the low scorers had an average level of improved performance. The result shares similarity with that of Badmus, et al [31], who found a significant difference in the achievement of the high, medium, and low scorers when cell division was taught using WebQuest Instructional Package in favor of the low scorers. On the other hand, the findings contradict those of Olarewaju [30], who claimed that there was no significant variation in the performance of Chemistry students exposed to WebQuest instructional techniques based on their score levels.

Research Question 4: Is there a difference in the performance of students taught chemical equations using computer simulations based on their cognitive styles?
Research Hypothesis 4: There is no significant difference in the performance of students taught chemical equations using computer simulations based on their cognitive styles.

Table 8 compares the performance of field-dependent, and field-independent students taught chemical equations using simulations. The field-dependent and field-independent groups had comparable pre-test mean gain scores of 9.43 and 10.82, respectively, while the post-test mean scores were 16.63 and 18.73, respectively. Also, the field-dependent and field-independent groups' mean gain scores were 7.2 and 7.91, respectively. The two groups had a mean gain score difference of 0.71.

Table 8. Mean Gain Scores of Students' Performance Using Computer Simulations Based on their Cognitive Styles.

Cognitive Styles	N	Pre-test		Posttest		Mean Gain Score
		M (X)	SD	M (X)	SD	
FD	30	9.43	3.79	16.63	6.84	7.2
FI	22	10.82	3.47	18.73	4.28	7.91

FD = Field dependent
FI = Field independent

The *t*-test analysis of the mean gain scores of the students in the experimental group was further analyzed (Table 9). From the table, the t-value (t (50) = 0.93, *p*>.05) was not statistically significant at the .05 alpha level. Therefore, hypothesis 4 was retained, meaning there was no significant difference in the performance of students taught chemical equations using computer simulations based on their cognitive styles.

Table 9. t-test Analysis of Significant Differences in the Scores of Field Dependent and Field Independent Students' Performance in the Experimental Group.

Cognitive Styles	N	Mean Gain Score	SD	df	t	Sig. (2tailed)
FD	30	7.2	5.23	50	0.09	0.93
FI	22	7.91	4.13			

P > .05

This result could have resulted in field-dependent and field-independent students having equal access to the computer simulations. It is also a fact that the content was not tailored toward any cognitive style. The finding agrees with Murtala-Muhammad [36], who found that cognitive style did not influence students' achievement scores when taught using computer simulation.

However, this finding disagrees with that of Langkudi [37], who reported that students in the chemical group who were field-independent had higher achievement than the field-dependent students. The finding also disagrees with Musya [39], who found that field-independent individuals scored higher than field-dependent individuals. There are the findings of the study: (1) there was a significant difference in the performance of students taught chemical equations using computer simulations and those taught without computer simulations in favor of those taught using computer simulations, (2) there was a significant difference in the performance of male and female students taught chemical equations using computer simulations in favor of the male students, and (3) there was a significant difference in the performance between low, medium, and high scorers' students when they were taught chemical equations using computer simulations, with the high scorers' students outperforming the others, and (4) there was no significant difference in the performance of field-dependent and field-independent students.

4. CONCLUSION

This study concludes that computer simulations improved students' performance in chemical equations, particularly among male and high-scoring students, independent of cognitive styles. It means that computer simulation-based instructions enhanced students' performance in the topic ' of chemical equations. Hence, using computer simulations in teaching chemical equations can be advantageous to both the teacher and the students. It is also a significant advancement over the conventional teaching of chemical equations.

Based on the findings of this study, the following recommendations are proposed: The use of chemistry simulations should be encouraged in the teaching and learning chemical equations and other topics in Chemistry. Chemistry teachers should encourage both male and female students to utilize computer simulations to improve their performance in Chemistry and other science subjects. In contrast, teachers should pay better attention to females when they teach them with simulations.

In designing computer simulations for Chemistry teaching, particular attention should be paid to medium and low scorers so that they can benefit equally from the high scorers. Students, irrespective of their cognitive styles, should endeavor to use computer simulations and other ICT-related instructional strategies to improve their performance in chemical equations and other related difficult concepts.

Curriculum planners should integrate instructional strategies such as computer simulations into the curriculum and make it a vital instructional strategy for teaching and learning chemistry in senior secondary schools in Nigeria. Education and government stakeholders should organize seminars, workshops, and conferences to improve teachers' knowledge of computer simulations and other ICT-related application packages.

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