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Effects of Gender on Senior Secondary School Two Chemistry Students' Achievement and Retention in Chemical Equilibrium Using Computer Animation Strategy

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Abstract: *This study examined the effects of gender on senior secondary school two chemistry students' achievement and retention in chemical equilibrium using computer animation strategy (CAS). The pretest-posttest equivalent groups design was used. Three hypotheses were formulated and tested at 0.05 level of significance. Fifty students from two coeducational schools were sampled and randomly assigned into two equivalent experimental groups using students' performance in a chemistry achievement test (CAT) and mathematics achievement test (MAT). Each group contained 25 male and female students. The students were taught chemical equilibrium using CAS and a chemical equilibrium achievement test (CEAT) consisting of 30 multiple-choice items drawn from past Senior School Certificate Examinations was used for data collection (r = 0.78). Three research questions and three hypotheses were answered and tested using mean and standard deviation and t-test (α = 0.05) respectively. The study revealed a significant difference between the mean achievement scores of male and female students taught using CAS, and a statistically significant difference between the mean retention scores of male and female students also in favour of males. The study recommended CAS for teaching male students' chemical equilibrium and a combination of strategies for mixed classes.*

Key Words: *Achievement, chemical equilibrium, retention, computer animation strategy*

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Introduction

The impact of science, technology, engineering and mathematics (STEM) on humanity can never be over-emphasized. The influence is so much that it is now difficult to imagine what the world would be without the tremendous benefits we derive from them. The influence on our daily lives can be seen in the areas of communication, health, agriculture, transportation, housing, and industrial operations amongst others (Gongden, 2015). They have been very influential in promoting the economic growth of nations (Henriksen, et al., 2015). Chemistry occupies a pivotal position in science and technology and is considered the hub of science and it is considered a service subject (Jamil & Mahmud, 2019). As one of the branches of physical sciences, it deals with the composition, structure, and properties of substances and the changes or transformations that the substances undergo (Gongden, 2015). Of the science subjects, chemistry stands out as the subject upon which the bulk of technological breakthrough is built. It occupies a unique position in science education such that students offering courses such as medicine, biology, pharmacy, physics, biochemistry, microbiology and home economics among others, are required to take chemistry. The knowledge of chemistry is brought to play in the manufacture of products that improves man's luxury such as herbicides, insecticides, plastic products, foams, drugs and clothing

materials, just to mention a few. Most industries rely on physical chemistry principles for their operations. One such principle is Le Chatelier's principle in the concept of chemical equilibrium. Chemical equilibrium is the balance in the rate of two opposing reversible reactions with no change applied to the system with applied constant pressure and temperature (UK Essays, 2018). The knowledge of chemical equilibrium and applications of Le Chatelier's principle is usually brought to bear in the manufacture of ammonia by the Haber process and in the manufacture of sulphuric acid by the Contact process where the formation of sulphur (VI) oxide is a necessary step. The processes are represented by the following equations:

$N_{2(g)} + 3H_{2(g)} \leftrightharpoons 2NH_{3(g)} + \text{energy}$ (Haber Process)

$2SO_{2(g)} + O_{2(g)} \leftrightharpoons 2SO_{3(g)} + \text{energy}$ (Contact Process)

Both ammonia and sulphuric acid are very important industrial chemicals that serve as raw materials for the manufacture of several chemical products including fertilizers, explosives, nitric acid, etc. Generally, in industrial processes, it is important to get the product as quickly and as efficiently as possible. The less expensive the process the better. Chemical equilibrium principles are used to achieve these.

However, despite the central and pivotal role of chemistry in STEM and in sustaining sustainable economic growth and development, student's achievement over the years has not been encouraging (Nja Cornelius-Ukpepi & Ihejiamaizu, 2019; Nja, Cornelius-Ukpepi & Orim, (2019). Chemistry students do not learn chemistry concepts meaningfully, perform poorly in chemistry at both internal and external examinations, and cannot apply their knowledge to solve everyday problems in the society in which they live (Chikendu, 2018). Research carried out in the field of chemistry education revealed that one of the concepts which students find difficult or often misconceptions is chemical equilibrium. The West African Examination Council (WAEC) Chief Examiners Report WAEC, 2020 on chemistry results indicated that students were weak in chemical equilibrium concepts in the Senior Secondary School Certificate (SSCE). The students were unable to compare the rates of forward and backward reactions for a reversible reaction at time zero. Gongden (2015) had earlier reported that chemistry students experience misconceptions about this same concept. These misconceptions and learning difficulties are on the dynamic nature of equilibrium, the equilibrium constant, heterogeneous equilibrium, gases equilibrium and Le Chatelier principle. Students are, therefore, unable to perform tasks involving chemical equilibrium satisfactorily (WAEC, 2020). This affects their achievement in examinations.

According to Gongden, et al. (2020), the contributing causes include the abstract nature of chemistry concepts, attitude, interest, students' perception (self-efficacy), student anxiety, motivation for chemistry learning, use of ineffective teaching strategies, teachers' professional and academic qualifications, etc. Research has shown that the continued use of the traditional lecture method for teaching all topics in chemistry has been ineffective. This has resulted in poor achievement in chemistry external examinations such as the Senior School Certificate Examination (SSCE) conducted by the West African Examination Council (WAEC) and the National Examination Council, NECO (Oloruntegbe & Odutuyi, 2015; Gongden, et al., 2020).

Research has shown that the continued use of the traditional lecture method for teaching all topics in chemistry has been ineffective (Hussain, et al., 2017; Gongden, et al., 2020). This has resulted in poor achievement in chemistry external examinations such as the Senior School Certificate Examination (SSCE) conducted by the West African Examination Council (WAEC) and the National Examination Council, NECO. A variety of teaching strategies have been advocated for use in science and mathematics classrooms, ranging from a teacher-centred approach to more student-centred ones. These include the use of concept maps and advanced organizers, computer

animations, use of analogies, cooperative learning, hands-on activities, conceptual change, problem-solving, inquiry-oriented approaches, experiential learning, role-playing, etc.

Retention is the ability to retain and recall information or knowledge gained after learning. One of the factors for the low achievement in science is lack of retention (Obinna, et al., 2021). Aminu (2011) defined several variables that affect retention including; the content or tasks to be performed, learners' past experiences, the interval between lesson and evaluation and instructional strategies employed. Atadoga and Onaolapo (2008) however, noted that the critical factor influencing the retention of students is the level of the learning experience provided in the lesson. It is their view that when the learning process engages more senses, a rich learning environment and experience are created. To engage the students meaningfully in the learning process, the teacher must have to adopt innovative teaching methods such as an animated-media instruction strategy.

According to Chikendu (2018), computer animation is a set of varying images presented dynamically according to users' actions in ways that help the user perceive a continuous change over time and develop a more appropriate mental model of a task. A typical example of computer animation could be likened to the robot which is seen on television performing the action of cooking or gathering items into a basket. Computer animation is a product of modern technologies. It is a computer-generated series of still computer-generated pictures that are presented in succession to create the illusion of motion, much like a picture. It produces special effects and stimulates images that would be impossible to show with non-animation techniques. The instructional effectiveness of computer animations may be explained using Paivio's dual-coding theory, which assumes that learners store information, received in their working memory as either verbal or visual (pictorial) mental representations (Ardac & Akaygun, 2004). Studies have suggested that students who receive instruction including computer animations or visualizations of chemical processes at the molecular level are better able to answer conceptual questions about particulate phenomena. Several studies have shown that computer animation instruction had significant effects on students' academic achievement in Chemistry (Kelly & Jones, 2007; Su, 2008; Westhoff, 2008; Ikwuka & Samual, 2017). Islam, et al. (2014), stated that the use of multimedia animation as teaching media improved students' thinking process in chemistry, leading to higher achievement. Investigating the effects of ICT on students' retention shows that it is more effective on students' retention as compared to traditional teaching methods (Hussain, et al., 2017). These studies show that the use of visualization is important for teaching chemistry concepts. They also established the effectiveness of computer animation. Animation can be used to give an accurate and rich picture of the dynamic nature of molecules and molecular interaction, which are often very hard to grasp from text-based presentations of information. This is particularly important for a topic such as chemical equilibrium which has proved to be abstract and difficult to understand. Perhaps when the basic concepts are visualized, the whole chemical phenomena may become more meaningful, relevant, enjoyable, easy and understood. This is where animation instructional strategies become necessary.

Gender is a major factor that influences career choice and the subject interest of students (Ezeudu, 2013). Okeke (2008) looks at gender as the socially culturally constructed characteristics and roles which are ascribed to males and females in any society. Several studies such as Adesoji and Babatunde (2008), Ezeudu (2013), Gongden (2015), Gongden (2016), and Gongden and Gongden (2019), have over the years, been committed to the effects of gender on students' performance in chemistry and other science subjects. Studies on gender differences in chemistry achievement have, however, continued to yield inconsistent results and it has usually been attributed to unequal exposure of males and females to learning instructions relevant to chemistry learning. Oluwatosin

and Josiah (2017) found that gender difference did not influence students' achievement in Stoichiometry as both performed similarly. Udousoro (2003), had earlier reported a similar finding that there is no significant difference in the academic achievement of male and female students in chemistry. Adesoji and Babatunde (2008) in a study concerning problem-solving performance in inorganic chemistry, found that female students encountered problem-solving difficulties in inorganic chemistry more frequently than their male counterparts. In another study, Okereke and Onwukwe (2011) showed that male students achieved better than female students. Similarly, Gongden (2016) found that male students achieved higher than female students when taught mole and stoichiometry using analogies. However, Armagan, et al. (2009), reported a situation in favour of females when they investigated the effect of problem-solving skills on the achievement of male and female chemistry students. Chikendu (2018) also reported better student achievement and interest in chemistry by female students over their male counterparts when taught using instructional computer animation. These studies show that there exist gender differences in science achievement among secondary school students the world over. The issue of gender in chemistry achievement has not yet been resolved. It does appear that these gender differences in students' achievement vary with the method of instruction, hence the need for further study to determine the effects of gender on students' achievement and retention in chemical equilibrium using a computer animation strategy.

Oluwatosin and Josiah (2017) reported that gender difference had no influence on students' achievement in Stoichiometry when taught using animated- media strategy but that the strategy proved effective for both male and female students.

Purpose of the Study

The study aimed at finding out the effects that gender has on the achievement and retention of male and female students in chemical equilibrium when taught using computer-animated media. The specific objectives were:

i. To find the difference between the pretest mean scores of the male and female students in a chemical equilibrium achievement test, CEAT
ii. To find the difference between the posttest mean scores of the male and female students in a chemical equilibrium achievement test, CEAT after teaching using computer animated strategy
iii. To find the difference between the mean retention scores of the male and female students in a chemical equilibrium achievement test, CEAT after four weeks of teaching using computer animated strategy

Research Questions

i. To what extent do the pretest mean scores of male students differ from that of female students in a chemical equilibrium achievement test, CEAT?
ii. What is the difference between the posttest mean scores of the male and female students in a chemical equilibrium achievement test, CEAT after teaching using computer animated strategy?
iii. How do the mean retention scores of male students differ from that of female students in a chemical equilibrium achievement test, CEAT after four weeks of teaching using computer animated strategy?

Research Hypotheses

The following research hypotheses guided the study.

H_{O1} There is no significant difference between the pretest mean scores of the male and female students in a chemical equilibrium achievement test, CEAT

H_{O2} There is no significant difference between the posttest mean scores of the male and female students in a chemical equilibrium achievement test, CEAT after teaching using computer animated strategy

H_{O3} There is no significant difference between the mean retention scores of the male and female students in a chemical equilibrium achievement test, CEAT after four weeks of teaching using computer animated strategy

Methodology

The research design used for this study was the pretest-posttest equivalent group design because of the experimental nature of the study. The population for this study consisted of all secondary school chemistry students studying schools in Jos South Local Government Area of Plateau State – Nigeria. The sample was made up of fifty (50) students drawn from two coeducational schools that offer chemistry at the Senior School Certificate Examination (SSCE) level. This sample consisted of 25 male and female students each. The male and female students were sorted into equivalent groups based on a Chemistry achievement test (CAT) and Mathematics achievement test (MAT) initially given to test their chemistry and mathematics background knowledge.

The research instruments were the chemistry achievement test CAT, the mathematics achievement test MAT, and the chemical equilibrium achievement test, CEAT. Each of the CAT and MAT is composed of thirty objective questions from senior secondary one (SS1) chemistry and mathematics curricula respectively but drawn from past SSCE. The researcher sampled the 2016-2021 chemistry objective question papers and picked out those that are on chemical equilibrium. The areas covered include definitions, the equilibrium constant for different reactions, factors affecting chemical equilibrium, Le Chatelier's principle, and applications (uses) of chemical equilibrium amongst others.

The CEAT was constructed to measure the pre-test and post-test students' knowledge. Even though the questions were standardized – having been drawn from previous SSCE, the researcher still went ahead with the validation of the instruments. The validity of the test instruments was confirmed with the help of three experts in the relevant fields. The reliability of each instrument was determined using the Pearson Product Moment Correlation formula and corrected using the Spearman-Brown formula. Using this method, the reliability coefficients were found as follows: CEAT = 0.78, MAT = 0.77 and CAT = 0.81. These indicated that the research tools were reliable and within statistical limits.

The researcher selected two coeducational Government secondary schools in the study area using a purposive sampling technique. The selection ensured that both schools had the same proprietor, operate under the same if not similar conditions and the chemistry teachers that were of the same qualifications. The researcher obtained the necessary permission from the principals and arranged two meetings with the chemistry teachers (research assistants) of the selected schools to explain the purpose of the study and its procedure. Thereafter the senior secondary two (SS2) chemistry students were administered the CAT and the MAT and their responses scored out of 100. The purpose of this was to test their background knowledge in mathematics and chemistry. Those who scored above 50 in each case were used as respondents for the study. From the respondents, the researcher randomly selected 25 students from each of the schools – made up of male and female students. In all, there were 25 males and 25 females that made up the sample. However, before the administration of treatment, a pretest (CEAT) was administered to the group to determine their prior knowledge related to the chemical equilibrium concept. However, before the administration

of treatment, a pretest was administered to the group to determine their prior knowledge related to chemical equilibrium concepts. Since there was no control group, the students were taught in each school by the research assistants using computer animation strategies. Each teacher was equipped with a laptop computer and projector for a PowerPoint presentation of animated reversible reactions and chemical equilibrium. After the treatment, students were administered the same CEAT as the posttest but with the questions reshuffled. Students' scripts were scored and the pretest and posttest scores were compared. After four weeks of the posttest, the same students were given the same CEAT to test their retention. As in the posttest, the questions were reshuffled.

Results

Hypothesis 1: There is no significant difference between the pretest mean scores of the male and female students in a chemical equilibrium achievement test, CEAT.

Table 1: Independent sample t-test of the difference in pretest scores of male and female students in the chemical equilibrium test

Groups	N	Mean	S.D	df	t- value	p-value	Remark
Male	25	68.62	3.32	48	-0.389	0.699	Not significant
Female	25	68.24	3.58				

Table 1 showed a t-value of -0.389 and a p-value of 0.699. This indicates that no significant difference existed between the pretest achievement scores of male and female students in the chemical equilibrium achievement test ($p>0.05$).

Hypothesis 2: There is no significant difference between the posttest mean scores of the male and female students in a chemical equilibrium achievement test, CEAT after teaching using computer animated strategy

Table 2: Independent sample t-test of the difference in post-test scores of male and female students in the chemical equilibrium test

Groups	N	Mean	SD	df	t-value	p-value	Remark
Male	25	88.29	3.38	48	-16.394	0.000	Significant
Female	25	72.36	3.49				

Table 2 showed a t-value of -16.394 and a p-value of 0.000. This indicates that a significant difference existed between the posttest achievement scores of male and female students in the chemical equilibrium achievement test ($p>0.05$), and in favour of the male students.

Hypothesis 3: There is no significant difference between the mean retention scores of the male and female students in a chemical equilibrium achievement test, CEAT after four weeks of teaching using computer animated strategy

Table 3: Independent sample t-test of the difference in retention scores of male and female students in the chemical equilibrium test

Groups	N	Mean	St. Dev.	df	t-value	p-value	Remark
Male	25	86.32	3.46	48	-17.829	0.000	Significant
Female	25	69.32	3.52				

Table 3 showed a t-value of -17.829 and a p-value of 0.000. This indicates that a significant difference existed between the retention scores of male and female students in the chemical equilibrium achievement test ($p>0.05$), and in favour of the male students.

Discussion of Results

The study sought to find out the effects of gender on the achievement and retention of male and female students in chemical equilibrium when taught using computer-animated media. The results that emanate from the study showed that there was no statistically significant difference between the achievement of male and female students on the pre-test. This was to be expected given the fact that the respondents were equivalent and hence, of equal or similar capabilities. As far as students' performance on the pretest is concerned, both groups were the same before the experimental treatment.

The study also found a statistically significant difference between the posttest achievement of male and female students taught chemical equilibrium using computer animated strategy. The male students performed very well when compared with the female students. This finding is consistent with that of Ikwuka and Samuel (2017). Ikwuka and Samuel (2017) found that gender had a significant effect on the academic achievement in Chemistry of male and female students who were taught using computer animation in favour of males. Generally, there is a common belief that science is masculine-oriented which creates a barrier to the active participation of females in the field. Traditionally, sciences have been taken to be masculine-oriented while arts subjects, according to Agu (2002) have been perceived as feminine subjects at the school level. At O' level examinations, boys do well in science subjects while girls excelled at art subjects. Okeke (2007) stated that science has a masculine image which becomes a barrier to the active participation of females in science education. This finding is however, in contrast to that of Chikendu (2018) who found that female students performed better than male students taught using instructional computer animation in a study on the effects of instructional computer animation on secondary school student's achievement and interest in chemistry. It is also at variance with that of Armagan et al. (2009) who reported in favour of females when they investigated the effect of problem-solving skills on the achievement of male and female chemistry students. Oluwatosin and Josiah (2017) reported that gender difference had no influence on students' achievement in Stoichiometry when taught using animated- media strategy but that the strategy proved effective for both male and female students.

The study also found a statistically significant difference between the mean retention scores of the male and female students in a chemical equilibrium achievement test. The male students performed better than the female students when tested four weeks after treatment using computer animated strategy. The result is contrary to that of Obinna, et al (2021) who, in a study on the effects of animated-media instructional strategy on students' retention in chemistry, found that there was no significant difference in the mean achievements of male and female students taught using animated media strategy. Gongden (2021) also reported no significant difference in the retention scores of male and female students taught chemical kinetics using reciprocal peer tutoring It also varies with that of Akpoghol et al. (2016) who reported a significant difference in retention score in favour of female students. This happened when senior secondary school students were taught electrochemistry with lecture methods supplemented with music and computer animation. However, Nwoke et al. (2021) in a study on gender achievement and knowledge retention in mathematics using animation established no significant difference between the retention scores of male and female students.

Conclusion and Recommendations

This study added to existing literature concerning the teaching of chemistry, especially the concept of chemical equilibrium. It shows that the computer animation strategy cannot be used in a class of both sexes. It showed that gender is a variable in teaching chemistry that must be taken seriously.

Gender was found to play a significant role in determining the achievement and retention of the students in a chemical equilibrium achievement test when they are taught using a computer animation strategy. Based on the findings of the study on the effects of gender on achievement and retention using computer animation strategy in teaching chemical equilibrium, the researcher recommends that the strategy be used only in single-sex (male) classes only. The strategy should be used in conjunction with other strategies when teaching chemistry classes involving female students.

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