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THE EFFECTS OF A WEB-BASED COMPUTER SIMULATION ON STUDENTS' CONCEPTUAL UNDERSTANDING OF RATE OF REACTION AND ATTITUDE TOWARDS CHEMISTRY

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Abstract. *This study established the effects of a web-based computer simulation on the conceptual understanding of the rate of chemical reaction and attitude of 66 first year secondary school (SS1) students in Niger state, Nigeria towards chemistry. A pre-test and post-test experimental design was used during which students were randomly assigned into either the experimental or the control group. The 'Rate of Reaction Knowledge Test' (RRKT) and the 'Chemistry Attitude Scale' (CAS) was administered. Classroom observations and structured interviews with the students yielded additional qualitative data. The results showed that a statistically significant difference was found between the groups and that the web-based computer simulation improved students' development of mental models on rate of reaction in comparison to the students in the experimental group. The students in the experimental groups also indicated that they liked using the software learning tools. The findings support the notion that chemistry teachers should be trained or re-trained in the use of web-based computer simulations for teaching chemistry. It places an onus on educational authorities to procure web-based simulations for use in teaching chemistry and other science subjects in secondary schools.*

Key words: *attitude to chemistry, conceptual understanding, rate of reaction, web-based computer simulation.*

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Introduction

The adoption of web-based computer simulation for teaching and learning purposes in the developing world educational context is currently gaining wide acceptance. Web-based computer simulation enhances learning experiences by supporting knowledge impartation in the class room. A web-based computer simulation is described as a computer program that incorporates text along with one or more of the following: audio, music, video, photographs, 3-D graphics, animation, or high resolution graphics in order to enhance learners' understanding (Maddux, 2003). For a developing country like Nigeria to attain technological advancement, there is a need to motivate secondary students' interest in learning science, technology, engineering and mathematics (STEM) related subjects. Edomwonyi & Avaa (2011) are of the opinion that technology advancement will play an important role to elevate Nigeria from being a developing country to being a developed country. Nigerian education policy emphasises the importance of science teaching and learning within the curriculum and that chemistry should be taught in the senior secondary school classes one to three (Federal Ministry of Education, 2007). The aims of the curriculum include, among others: developing interest in STEM subjects; acquiring basic skills, theoretical and practical knowledge in STEM; and developing reasonable level of competence in information computer and technology (ICT) application in order to engender entrepreneurial skills (National Policy on Education, 2008). The development of students' interest in STEM learning has always been recognised to be of great importance to enable them make decisions wisely and to perform efficiently in the STEM subjects.

There are important reasons for learning chemistry. Chemistry is distinct from other sciences in the sense that it is perceivable in almost every part of the daily lives of humans. Chemistry is at work in the food we eat, the clothing that we wear and in the cleaning agents that we use. However, it is often

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challenging for students to understand the manifestation of chemistry as a science during the daily phenomena that they observe or experience. Therefore, it can be said that students struggle to associate concepts of chemistry with various human activities. Arong and Ogbadu (2010) identified that Nigerian students usually perform poorly in chemistry at the senior school certificate examination (SSCE) due to poor teaching methods, lack of appropriate educational materials, and a poor attitude to chemistry resulting from a lack of interest in the subject. They also indicated that gender affects performance in chemistry. In addition, Olatoge and Atuwape (2004) and Adesoji and Ogini (2012) found that poor performance in SSCE chemistry is due to the poor academic background of students in basic sciences being taught at the junior secondary schools (JSS).

A particularly difficult concept in chemistry education has been found to be the 'rate of chemical reaction'. It is an abstract concept that students find difficult to understand, and some teachers find difficult to teach because of misconceptions concerning the rate of chemical reaction (Çakmakç, Leach, & Donnelly, 2006). The rate of chemical reactions encapsulates several fundamental chemistry concepts including factors affecting reaction rates, theories of reactions rates, analysis and interpretation of reaction rates graphing, and collision of constituent molecules in chemicals. Therefore, it is important that secondary school students who study chemistry understand its manifestation in everyday life and that they are able to explain them scientifically as they happen. Nigerian school class rooms presently do not provide learning opportunities that require hands-on-activity and that are engaging with collaborative or interactive learning settings that would help relate chemistry concepts to everyday life. These learners already have access to the internet on their mobile phones and use other sophisticated electronic gadgets. Therefore, learning opportunities without fun are becoming daunting to them, hence they are not interested in science subjects especially chemistry. This, however, could be responsible for their mass failure at the final SSCE.

The educational goals related to science education as encapsulated in Nigerian education policies could possibly be addressed by the exploration of new teaching methods that attenuate the need of learners to engage with learning in a similar way that they engage with the internet on their mobile phones. Therefore, web-based computer simulations which entail multimedia representations could aid students' development of mental representations related to concepts in chemistry. Simulations can help in facilitating learning processes through representation and practice in a repeatable, focused learning environment (Aldrich, 2004). Mayer (2005) noted that web-based computer simulation learning is a rigorous task that entails selection of relevant words and images; organising them into coherent verbal and pictorial representations; and synthesising the verbal and pictorial representations with each other and mapping them with students' prior knowledge. It has been agreed generally that the availability of the state-of- the-art visualisation technologies is not a sufficient indication that instructors and students are well informed to use them. According to Chen et al, (2013), simulations provide near-authentic learning environments, simulating contexts for task-based learning. Simulation programmes can be applied to chemistry by providing real life settings for the application of chemistry concepts. Simulations include role plays, games, and computer programmes that encourage students to become active participants in chemistry classrooms.

In this research, a web-based computer simulation was used for teaching chemistry, based on the assumption that it will help students in understanding the abstract and difficult concepts in the content. Students were allowed to experiment on variables that constitute the different concepts associated with the rates of chemical reaction. Simulations can help students to develop their own understanding of chemistry concepts. It can also help the students to be independent problem solvers. Chen & Howard (2010) observed that the use of simulations to teach chemistry results in positive learning gains over time. Therefore, simulations can address the need for the desired objectives to be met: the need for cognitive understanding, knowledge construction, and collaboration that are facilitated by using a web-based computer simulation for teaching and learning of rates of chemical reactions.

For meaningful learning to take place in web-based computer simulation learning environments, learners are expected to construct coherent integrated representations. Literature shows that learning via web-based computer simulation is essentially improved if learners could engage in deep knowledge construction and integration activities (Wong, Lawson & Keeves, 2002). The literature also reveals that learners' ability to construct knowledge is less in text-based content, and greater in the diagram context, and intermediate in the multimedia (Wong, *et al.,* 2002; Ainsworth & Loizou, 2003). Therefore, it appears that the more information students assimilate in different forms to make sense of the learning materials, the greater the impact of the level of understanding of the learning content.

Chang, Quintana & Krajcik (2010) investigated the effects of computer-based multimedia on grade seven learners' performance in science class. They found that the group of students who learnt science using a computer-based multimedia learning environment, outperformed those that were taught using the traditional method of instruction. Moreover, Chien and Chang (2012) in their study also stressed the positive effects of computer-based learning environment. In the study, students were randomly assigned into three forms of computer-based multimedia which contained static graphics, simple learner-pacing animations and full learner-pacing animations for learning topographic measurement. The full learner-pacing animation was designed in such a way that the students could manipulate the virtual measuring mechanism rather than passively observe dynamic or static images. The study showed that the practical performance of the student in the full learner-pacing animation group was better than the other two groups. Therefore, full learner-pacing animation attained better learning outcomes than static graphics and simple learner-pacing animations. Furthermore, previous studies have also shown that computer-based simulation learning environments enhanced students' development of metacognitive skills and helped them to learn in a meaningful way leading to increased students' achievements over the traditional rote-memory learning that prevails (Serin, 2011; Ercan,2014).

This research which determines the effects of using a web-based computer simulation for teaching rates of chemical reaction, is thought to be important as it will contribute to learning how teachers can make effective use of educational software, and specifically web-based simulations in their teaching in order to improve students' conceptual understanding and active participation during learning within Nigeria educational system.

Theoretical Framework

Many theorists had advocated for effective learning involving active participation of the learners during learning processes. It has been noted that for effective learning to take place, serious consideration has to be given to the contextual setting in which it occurs. This idea is founded on the work of Vygotsky. Vygotsky (1978) emphasised on social interaction as the best ways of learning. The major theme of Vygotsky theory is that social interaction plays a fundamental role in the development of cognition (Vygotsky, 1978). According Vygotsky (1978), a constructivist teacher is the one who creates a context for learning in which students can become engaged and be interested in learning activities being learnt. Vygotsky opined that learning depends on development, but development is not dependent on learning. Development can be enhanced via effective instruction. Vygotsky social theory is applied in this study since web-based computer simulation involves role plays and computer programmes that encourage students to become active participants in the learning of rates of chemical reaction. Students are able to learn better when they have social interaction among themselves and the relevant learning resources. In this study, the teacher through the help of the researcher created a context for interactive learning in which students were expected to construct knowledge in their own understanding. Teacher and the researcher facilitated cognitive growth and learning that took place in a web-based computer simulation.

Research aim

The aim of the research was to determine the effects on academic performance and the attitudes of SS1 students who were taught rates of chemical reaction using a web-based simulation learning environment. The research attempts to answer the following research questions:

- What are the effects of web-based computer simulation learning environment on students' academic achievement when learning rate of chemical reaction?
- Are there any differential effects of web-based computer simulation on male and female students' achievement in rate of chemical reaction?
- What are the effects of web-based computer simulation on students' attitudes towards learning chemistry?

Methodology of the Research

An experimental pre-test-post-test control group design was used in this research during which participants were randomly assigned to either an experimental group or a control group. The research setting was a secondary

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school in Minna, Niger state, Nigeria. The experiment was conducted over a 3 week period during the 2012–2013 Nigerian academic year. The concept of rates of chemical reaction is taught at the time of this research at the school. Students attended a series of lessons for two hours a week during the 3 week period. For the purposes of this research, in order to protect the anonymity of the students, who were minors, a pseudonym is assigned to the school: Niger Valley Secondary School (NVSS). The research was conducted at NVSS because the school is one of the schools in the state that have computer suite that could accommodate this research. The researcher collaborated with the chemistry teachers and obtained permission from the school authority in carrying out the research. The participants assented to participate in the research by means of letters of assent, and parents and guardians also signed consent letters.

Sampling

Sixty six first year senior secondary (SS1) science students were sampled. The sample represented the entire population of students who were enrolled at NVSS for chemistry. The students are usually taught rate of chemical reaction at this level in the national curriculum. Thirty four students were randomly assigned to the experimental group and 32 students were assigned to the control group. Experimental and control groups were taught by the same teacher who can use computer and internet properly. Prior to the research, lessons were planned for both groups which included the same content.

The control group was taught following the normal conventional method as stated in the national curriculum while the experimental group was taught with the web-based computer simulation identified by the researcher. The experimental group was taught in the computer suite under the guidance of the teacher and the researcher.

Instrument

For the purposes of this research, a 'Rates of Reactions Knowledge Test' (RRKT), a 'Chemistry Attitude Scale' (CAS) and a 'Class Activity on Rate of Reaction (ARR)' were developed by the researcher, for the purpose of this study. The developments of the instruments are now described.

Rates of Reactions Knowledge Test (RRKT)

The researcher developed the RRKT to measure students' achievement on rate of chemical reaction for both experimental and control groups before and after the implementation of a web-based computer simulation intervention. The RRKT consisted of a 14 item paper-based test on the rates of chemical reactions, and that represented the conceptual knowledge of the construct. The items comprised short-answer questions, matching, and multiple-choice tasks. The pre-RRKT and post-RRKT were identical in the study, as these tests aimed to capture students' conceptual knowledge of rate of chemical reaction before and after learning in their various groups. The face validity of the RRKT was confirmed by the four teachers who are experts in the field. They examined the test to make sure that the items were suitable for the students, and representative of the content associated with rate of chemical reaction. In the RRKT, the minimum score was 0 and the maximum was 14. Higher scores indicated higher attainment of conceptual knowledge of rate of chemical reaction.

Class Activity on Rate of Reaction (ARR)

In order to gain deeper understanding into students' conceptual understanding, students were asked to diagrammatically explain how the rates of chemical reaction between zinc granules and hydrochloric acid is affected firstly with concentrated acid and later with diluted acid before and after the intervention.

Chemistry Attitude Scale (CAS)

The Chemistry Attitude Scale (CAS) developed by Demircioğlu, Ayas & Demircioğlu (2005), and contains of 25 attitude statements (11 positive and 14 negative) using five-point Likert-type scale responses ranging from strongly agree, agree, undecided, partially disagree, and strongly disagree. For negative items, the responses were reverse coded. Therefore, the potential scores from the CAS ranged from 25 for lowest to 100 for the highest. CAS's Cronbach alpha reliability coefficient was found to be 0.84. Examples of items include: *I like chemistry*; *Chemistry lessons are boring for me*; *It is not interesting for me to try solving chemistry problems; I enjoy learning how to use chemistry in daily life.* CAS was analysed by first of all calculating the total score of each student and then mean scores of each group were computed. The mean scores of the experimental and the control groups were compared by using a t-`test for both the pre-tests and post-tests.

Observations and interviews

Qualitative data were collected through classroom observations by using an observation checklist of how students were learning in a web-based simulation learning environment. After the learning sessions, students in both groups were interviewed in which the students were asked to use a "think aloud" protocol to verbalise freely what they were thinking throughout their experience with rates of reaction concept. The goal was to "get inside the student's head" and elicit what they were doing and why as they engaged the web-based simulation.

Procedure

The RRKT was piloted with 60 SS1 students in another school and the four teachers who were involved in this study to check the content validity and the reliability of the instrument. During the first lesson of this research, students in both experimental and control groups completed the pre-RRKT and pre-CAS. They were given 20 minutes to complete the RRKT and CAS. Students were also given a pre-class activity on rate of chemical reaction before the intervention. During the second lesson, students in the experimental group were introduced to the web-based computer simulation program involving the rate of chemical reaction unit. Students sat with each person having their own computers and the teacher instructed them using a prepared PowerPoint presentation. After the teacher's presentation, the students had the opportunity to work on the activity using their computers. The control group students were taught by the same teacher using the traditional teacher-centred approach involving 'talk-and-chalk' type lesson which is the dominant teaching approach in the Nigerian schools.

After the intervention, the RRKT and CAS were administered to each group. Each group was also asked to carry out the class activity on how the rates of chemical reaction between zinc granules and hydrochloric acid is affected by concentrated and diluted hydrochloric acid. These diagrams and explanatory notes give an indication of how SS 1 students organised their knowledge as well as constructed their understanding of the learning content. Both experimental and control groups were observed during the implementation of the activity on rates of chemical reaction by the researcher and the teachers.

The Learning Environment

In order to achieve the aims of this research, an interactive web-based computer simulation learning environment about the rate of reaction learning activity was constructed. The learning environment comprised a web-based computer simulation from the *s-cool website (*www.s-cool.co.uk*)*. The simulations on the website are curriculum-focused and designed to help teachers in tackling problematic topics in secondary biology, chemistry and physics. The research made use of the rate of chemical reaction simulation for investigating students' conceptual understanding of rate of chemical reaction and attitude towards chemistry.

During the lesson, students in the experimental group were supported and motivated to make connections between the chemical worlds of macroscopic, microscopic and symbolic in order to demonstrate that they understand the chemical concept of the process of rates of chemical reaction. The class activities were given to the students in order to observe how they had made connections between the chemical worlds. Figure 1 below shows example of the simulation that students worked with on the website.

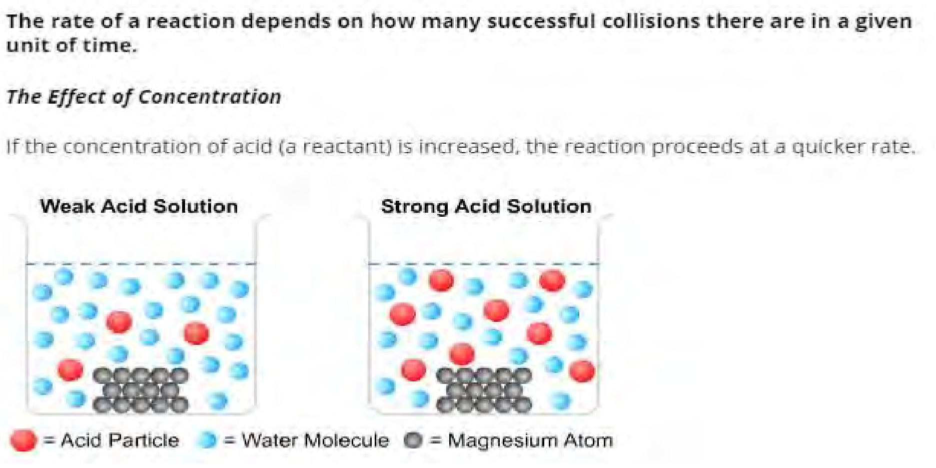


Figure 1: Simulation showing effect of concentration.

In order to demonstrate how much of the understanding of the rates of chemical reaction phenomena the students had gained, they were asked to use the microscopic world presented in the web-based computer simulation to give descriptions of how the rates of chemical reaction was affected by variation in the concentration of the acid in the macroscopic, microscopic and symbolic world.

Analysis of Data

An independent t-test was used to test the equivalence of the test scores on RRKT and CAS of the experimental and control groups at the beginning of the study. At the end of the experimental process, independent t-test was also used to compare the pre-test and post-test scores of the groups for each of the instruments. The significance level was taken as .05 in the study.

Students' answer scripts from the class activity were collected while their diagrammatic representations were examined in order to determine how the use of web-based computer simulations had improved their mental representation of rates of chemical reactions. Examples of these are presented in the next section.

Finally, the observation and the interview data were analysed by using thematic content analysis. This involved working with and organising the data, breaking the data into manageable units, synthesising the data in order to search for certain patterns, deciding on vital aspects and dissemination of the findings (Bogdan & Biklen, 2003). Therefore, the existence, meanings, and the relationships of the words or concepts that were related to attitude towards learning chemistry were explored and noted down during the process of analysis.

Results of Research

In order to evaluate the effectiveness of web-based computer simulation learning environment on students' performance, this study compared the academic performance scores of the experimental and control groups to each other and within themselves. The differences between pre-tests, post-tests, and attitude scores of both groups were also compared.

Students' Attainment in pre-RRKT and pre-CAS

An independent sample t-test was conducted to establish whether significant differences in RRKT and CAS scores between the experimental and control groups were found prior to the research. The results are presented in Table 1.

Table 1. Students' performance at pre-tests.

Groups	Pre-RRKT		Pre-CAS	
	M	SD	M	SD
Experimental	5.06	2.52	79.97	12.03
Control	5.81	2.75	79.16	12.18

The results show that there existed no significant differences in students' academic performance on rate of chemical reactions as well as their attitudes towards chemistry prior to this study t (64) = -1.161, p>0.05 for RRKT. For CAS, the results were t (64) = 0.273, p>0.05. The results reveal that both the experimental and the control groups were at the same level prior to this study.

Effects of Web-Based Computer Simulation on Students' Academic Performance

The independent sample t-test procedure which compares the shift in the means of test scores (Table 2) for the experimental and the control groups had been adopted with a view to determining whether a web-based simulation learning environment would be associated with a statistically significant level of shift in test scores as compared to traditional method of teaching. The shift in means for each group represents the difference in mean score between pre- and post-test scores.

Table 2. Means and standard deviation of shift in the test.

Groups	M	SD
Experimental	5.73	3.48
Control	1.31	3.78

The analysis revealed that there is a significant difference between the shift in the means of the test scores of the experimental group and the control group t (64) = 4.952, p<0.05. This result shows that web-based simulation had positive effects on students' achievement.

Comparison of the Pre-Test and Post-Test RRKT Scores of the Experimental Group

A dependent samples *t*-test was implemented to observe whether there were significant differences in the experimental group's academic performance scores prior to and after the intervention. The results are presented in Table 3.

Table 3. Comparison of the pre-test and post-test RRKT scores of the experimental group.

Time	M	SD
Pre-test	5.06	2.52
Post-test	10.79	2.41

Table 3 reveals a significant difference between the experimental group's pre-test and post-test academic performance scores, in favour of their post-test scores (t(33) = -9.622; $p < 0.05$). This result suggests that web-based simulation learning environment increased students' academic performance in rate of chemical reaction.

Effects of Web-Based Computer Simulation on Students' Attitudes towards Chemistry

An independent samples t-test was conducted to observe whether there were significant differences between experimental and control groups according to arithmetic means of the attitude scores and the results are provided in Table 4.

Table 4. Means and standard deviation of shift in the test.

Groups	M	SD
Experimental	25.26	16.93
Control	12.16	17.81

Table 4 reveals a significant difference between shift in the means of scores of the experimental and control groups, favouring the experimental group ($t(64) = 3.066$; $p < 0.05$). This result shows that of web-based computer simulation positively increased students' attitudes towards chemistry.

Gender Differences

An independent samples t-test was employed at investigating whether or not there were significant differences among genders in the experimental group's post-test academic performance scores. The results are provided in Table 5.

Table 5. Academic performance scores and gender.

Groups	M	SD
Male	10.80	2.42
Female	10.79	2.49

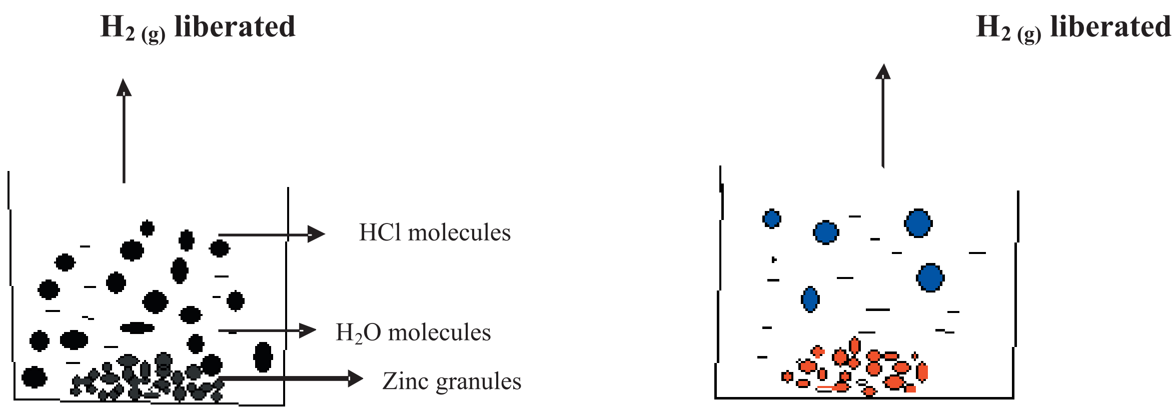
Table 5 shows t-test results of male and female students taught in a web-based simulation learning environment. The mean performance scores for male and female students are 10.80 and 10.79 respectively ($t(32) = 0.017$; $p > 0.05$). This result shows that there were no significant differences between male and female students' performance on rate of chemical reaction.

Students' Diagrammatic Representation of the Rates of Chemical Reaction Prior to the Research

The representations of the reaction between zinc granules and concentrated/diluted hydrochloric acid during the class activity on rates of chemical reaction were examined. When the drawings created in respect of the class activity question were studied, two types of drawings were found to have been made by both the experimental and the control groups before the intervention. Forty-two students made the first type of drawing shown in Figure 2. Acid molecules were represented by spheres in blue colour while the molecules of zinc granules were denoted with spheres in red colour. Hydrogen gas was shown to be liberated as zinc granules reacted with the acid in Figure 2. Moreover, this group of students were able to identify the products of the chemical reaction to be zinc chloride and hydrogen gas using appropriate chemical symbolic representation as shown below:

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2(g)$$

For the concentrated acid condition student A elucidated that "*more molecules were shown to depict concentrated acid condition (Figure 2a) while the diluted acid was represented with fewer molecules (Figure 2b)*". According to student B, "*the concentrated acid was viewed as being more effective in reacting with zinc granules than the diluted acid*". It was discovered during an interview that the group of students who drew Figure 2 derived their present conceptual understanding from their previous knowledge of chemical reactions between acid and metals. However, it was found that this group of students could not relate their present conceptual understanding to the effect of the change in concentration of acid on the rates of chemical reaction between zinc granules and hydrochloric acid as well as the quantity of hydrogen gas liberated. This is evident in the response of student C that "*I don't think concentrated acid will react faster or produced more hydrogen gas than diluted acid*" to the question "*will concentrated acid react faster than diluted one*". This question was asked as a prelude for the researcher to know if students were aware that concentrated acid could react faster or liberate more quantity or hydrogen gas than dilute acid prior to the intervention. Hence, it is evident that previous lessons on the reaction of acids with metals had helped the students to create correct chemical symbolic representation but incorrect diagrammatic representation of the rate of chemical reactions.



(a) Concentrated HCl reacting with zinc granules **(b) Diluted H Cl reacting with zinc granules**

Figure 2: Students' mental representation before the intervention.

Another fifteen students were discovered to have created the second type of representation as shown in Figure 3. Student D, one of this group of students, noted that "*the molecules of acids were represented as spheres reacting with zinc granules*". However, the students were unable to distinguish in their drawings the difference between the concentrated and diluted acids. A response from student E that "*how is concentrated acid different from diluted acid*" to the enquiry "*do you know that concentrated acid is different from diluted acid*" confirmed this claim. In addition, some of these students could not create correct chemical symbolic representation of the rate of chemical reaction while others were not aware of how to create chemical symbolic representation of the concept under investigation. Analysis of the students' activity sheets also revealed that they indicated water molecule to have been liberated instead of hydrogen gas molecules. Finally, this group of students could not explain how changes in concentration of acids had affected the rates of chemical reaction between zinc granules and acid as well as the amount of hydrogen gas liberated.

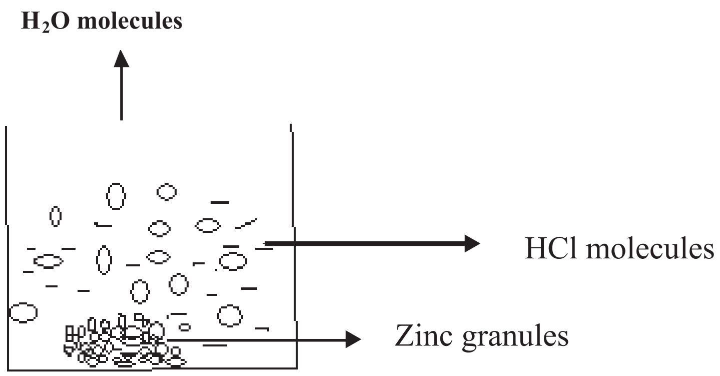


Figure 3: Students' mental representation before the intervention.

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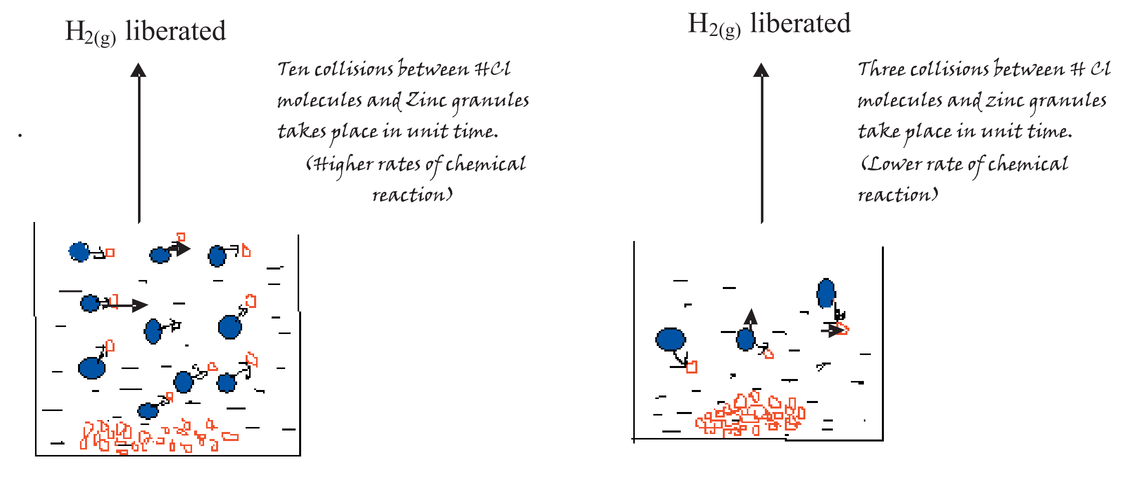
Finally, the remaining nine students had no idea of how to make the drawings of zinc granules reacting with hydrochloric acid in concentrated and diluted forms or the chemical symbolic representation of the concept being studied. In addition, this group of students could not also explain how changes in concentration of acids had affected the rates of chemical reaction between zinc granules and acid as well as the amount of hydrogen gas liberated.

Students' Diagrammatic Representation of the Rates of Chemical Reaction after the Intervention

After the intervention, students were asked to represent the reaction between zinc granules and concentrated and diluted hydrochloric acid diagrammatically again and proffer explanation what is happening. Students in the experimental group were able to produce improved mental representation after learning in a web-based computer simulation environment. Figure 4 shows that twenty-five students in the experimental group were able to make improved diagrammatic representation of the rate of chemical reaction in such a way that shows that they could select, organise and synthesise information using web-based computer simulation. Figure 4a shows concentrated acid with more molecules colliding with zinc granules much more frequently than in diluted acid (Figure 4b) with fewer numbers of acid molecules. Student F's explanation that "*it takes shorter time for the chemical reaction involving concentrated acid to be completed than for the diluted acid as a result of higher number of collision between acid and zinc molecules taking place in a unit time. Hence, increased collision between concentrated acid and zinc will liberated more hydrogen molecules than in the reaction involving dilute acid*" also affirmed this claim. Moreover, this sub-group within the experimental group were able to create correct chemical symbolic representation of the rate of chemical reaction as done prior to the intervention.



(a) Concentrated HCl reacting with Zinc granules (b) Dilute HCl reacting with Zinc granules

Figure 4: Students' in the excremental group representation after the intervention.

The other nine students in the experimental group as well as twenty-three students in the control group still created their diagrammatic representations as shown in Figures 2 and 3 respectively. Again, the remaining nine students did not even attempt the activity again.

Discussion

This study investigated the effect of web-based computer simulation on conceptual understanding of the rates of chemical reaction and attitude of students toward learning chemistry. The post-test academic performance scores of students as measured by RRKT for those who were taught with web-based computer simulation were found to be higher than those in the control group who were taught using the traditional method. The results presented above show there was statistically significant difference between the two groups t (64) = 4.952, p<0.05. These results are in agreement with previous studies in the field of technology enhanced learning. For instance, Westhoff, Bergman & Carroll (2010), Aktas, Bulut & Yuksel (2011) and Karacop & Doymus (2013) found in their studies that students taught using computer animation and simulation performed better than their counterparts taught using the traditional teaching methods. Likewise, in another study conducted by Hwang, Wu & Ke (2011) they found that using web-based materials together with concept maps enhance the students conceptual understanding of science and students developed positive attitude towards learning science. This present study also demonstrates that web-based computer simulation used in teaching rates of chemical reaction; a topic in senior secondary school chemistry; helps in raising students' conceptual understanding and improves their mental representations of the rates of chemical reactions. This situation was confirmed from the students' class activity. The analysis of various answers given by students in the experimental and the control groups show that students in the experimental group who used web-based computer simulation for learning rate of chemical reaction later produced a correct and meaningful representations as seen in Figures 4a and b. Non- of the students in the control group was able to produce mental representations similar to Figure 4. Therefore, it can be argued that the use of web-based computer simulation had a positive effect in raising teachers' awareness of students' misconceptions and lack of conceptual understanding with evidence of incorrect representations of the rates of chemical reaction. In a study conducted by Wang (2004), it was found that using multimedia such as computer simulation for learning is effective in raising students' awareness of how the learning contents affect their daily activities. For instance, students' responses to the question "*describe your learning experiences using a web-based computer simulation*" confirmed the findings from Wang (2004) as shown below:

> Student A: *"this simulation makes me to see the movement of the molecules and I now understand better why acid concentration affects rate of reaction as well as amount of chemical products. Therefore, I was able to draw the rates of reaction by indicating increased collision of acid and zinc molecules in unit time."*

> Student B: *"using this environment is better than just going to the lab to listen to my teacher. I was also able to understand how the liquid drug I use when I'm sick work faster than tablets because of increased surface area of liquid drug".*

From these examples, it is noted that the web-based computer simulation used in this study was very interactive and attractive to the students. In their study, Wang, Vaughn, & Liu (2011) examined the impact of animation interactivity on novices' learning of introductory statistics. Their findings concur with this present study in the sense that students who were taught statistics in an interactive learning environment improved better in their understanding than those taught using the traditional lecturing method.

This present study also investigated the relationship between students' post-test academic performance scores and genders. The result of the study shows that there was no statistical significant difference between the male and the female students' academic performance ($t(32)$ =0.017; $p > 0.05$). These findings show that irrespective of the instructional methods, male and female students benefitted equally, that is to say, the web-based computer simulation had the same effect rate on male and female students. This result is supported by Kickmeier-Rust, Holzinger, Wassertheurer, Hessinger, & Albert (2007) who investigated the gender-based effect of using text-based learning versus simulation-based learning for teaching blood flow. Their findings showed no gender differences in the usage simulation learning environment for learning. On the contrary, Anagbogu & Ezelioras (2007) study revealed that female students performed better than males in science process skills. From this present study, it implies that using simulation for teaching chemistry concepts could help eradicating gender stereotyping in science education within this context as all the students will enjoy and be motivated toward learning chemistry.

Moreover, the findings show that web-based computer simulation learning environments enabled the students in the experimental group to develop a better mental representation of the chemical reaction between zinc granules and concentrated and diluted hydrochloric. This result shows that web-based computer simulation was more effective in the development of mental models than learning chemistry using the traditional method of chalk and talk. The classroom observation reveals that students in the experimental group were more active in terms of their participation and involvement during learning process. They learned in the computer laboratory and each one had his or her own computer, hence, they participated directly in the learning process.

Another interesting finding from this study was that of the students' attitudes towards learning chemistry. The study shows that there existed significant differences between experimental and control groups in terms of the students in attitudes towards learning chemistry ($t(64) = 3.066$; $p < 0.05$). The students that were taught using a web-based computer simulation had positive attitude towards learning chemistry. Similar studies in literature had shown that simulation and multimedia enhance the development of positive attitudes towards chemistry (Hwang, Wu & Ke, 2011; Farhana & Zainun, 2012). It is also worth noting from the classroom observation and the interview with the experimental group that they liked learning rates of chemical reaction concept using web-based computer simulation adopted for this study. For example, when the students were asked to describe their willingness to learn chemistry using web-based computer simulation; first of all there was excitement on their faces.

> Student C: "*I just love it! I was able to produce a better diagram the second time because I understood how reaction takes place with concentrated and diluted acid with respect to time".*

> Student D: "*I just hope we will be learning other topics like this ehunn… I mean using simulation".*

From these evidences, it is believed that web-based computer simulation used in this current study had positive effects on the students' attitudes towards chemistry this could be because the simulation was attractive and was appropriate for the age group. In line with the findings of this research it is very crucial for the teachers to put the nature of the learning environment and the students' age group in consideration when designing or selecting multimedia environment that can enhance learning. Finally, this study encourages the adoption and development of web-based computer simulations for teaching different lessons in chemistry and other science subjects at senior secondary classes in Nigeria.

Conclusions

This research established the effects perform better in their academic performance scores as of a web-based computer simulation on students' conceptual understanding of rate of chemical reaction and attitude toward chemistry. Students who were taught with web-based computer simulation measured by RRKT than students who were taught using the traditional methods. Furthermore, this research also indicated that students who studied chemistry with the use of web-based computer simulation developed higher motivation to learn chemistry, in terms of: interest and enjoyment, and their ability to connect what they learnt to their everyday activities, in comparison to students who were taught chemistry using the traditional method. The success of the students in the experimental group in answering questions on the activity sheet with correct and meaningful representations can be explained by their engagement in three important cognitive processes: selecting, organising, and integrating. As students in the experimental group learnt with web-based computer simulation, they were paying attention to the movement of the molecules which means they are cognitively selecting images and text and as they work through the activities students were engaged in organising the newly introduced scientific concepts and integrating them into a coherent structure of knowledge. Lastly, the results show that the use of technology in the classroom is gender sensitive, this means that both male and female students achieved equally with the use of technology like web-based computer simulation.

The findings of this research provide administrators, teachers and other stakeholders with research-based information that supports the use of web-based computer simulations in teaching chemistry at senior secondary level of education in Nigeria. These findings will enable the school administrators and teachers to employ a wide variety of supplemental teaching strategies using technologies that will put gender issues into consideration. It will also enable the curriculum planners to design the national curriculum that allows active involvement and use of simulations for teaching and learning purposes.

In view of the positive results obtained from this research, it is therefore recommended that science teachers and teachers from other disciplines should be encouraged to integrate web-based computer simulations into their teaching and learning. The policy makers should encourage teachers to take part in in-service training on how to integrate various technological tools into teaching and learning processes in order to be able to enhance their students 'learning. In order to be able to generalise the findings of this research and increase its validity, further research should be conducted among students from different school within the state and from other states in Nigeria and the treatment should be administered for a longer period of time over the course of one academic year. Future research should also explore other science teaching strategies that can promote Nigeria students' desire to do science while keeping them actively engaged in their own learning process.

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