

The Effect of Using Computer Simulations in Teaching Chemical Bonding: Experiences with Ugandan Learners

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ABSTRACT Computer simulations are well documented in developed countries but little is known about them in developing countries. The objectives of the study were to examine the effect of using computer simulations in addition to hands-on (manual) laboratory activities when teaching chemical bonding and to compare the results with those of learners who were taught using hands-on (manual) laboratory activities only. Two senior three classes participated in the study: 58 learners in an experimental group (EG) and 57 in a control group (CG). Data from achievement tests were analysed using descriptive and inferential statistics, while data from interview schedules were thematically analysed. The results indicated that learners had little knowledge about chemical bonding. The EG performed better than the CG in the post-test (ANCOVA, $p < 0.05$). This suggests that computer simulations provide feedback that minimises abstractness. Also, there were no differences between achievements of the boys and girls in the EG ($U = 3.0.5$, $P < 0.05$), suggesting that computer simulations do not discriminate against gender.

I. INTRODUCTION

Computer simulations have become a popular method of instruction in the last 15 years (Quellmalz et al. 2012; Donnelly et al. 2012) and this is because of commercially available software that is based on scientific and technological models which replicate actual situations. In addition, Rutten et al. (2012) who reviewed 51 articles from 2001 to 2010 show that traditional classroom can be improved by using computer simulations. These simulations enable learners to view events, processes and activities that otherwise may not have been available to them (Bilan 1992). Using computer simulations has been reported to increase learners' gains up to a maximum effect size of 1.54 (Rutten et al. 2012; Donnelly et al. 2012) and other gains were reported by Howe et al. (2013) where children worked in pairs rather than working individually.

Although at first, computer simulations were mainly used in applied fields such as aviation and medical imaging, these technologies have now edged their way into science classrooms (Strangman and Hall 200; Kaheru et al. 2011; Quellmalz et al. 2012). Computer simulations have been given different meanings by different authors; however, in a broad sense, simulations are imitations of systems (Chung and

Newman 2000). Computer simulations are therefore computer-generated versions of real-world objects. Computer simulations 'provide near-authentic environment, context and situation for task-based learning' (Chen et al. 2013: 172). For example, demonstrating how chemical molecules and processes take place can be observed on a computer screen in many different forms, ranging from 3-dimensional geometric shapes to highly interactive, computerised laboratory experiments (Strangman and Hall 2003).

Globally, many learners experience difficulties in understanding chemistry concepts because of the manner in which they are taught and as a result many learners form misconceptions in this regard (Özmen 2009). In order to minimise these misconceptions, computer simulations are employed in science education (Barnea and Dori 1999; Akpan and Andre 2000; Michael 2001; Huppert et al. 2002; Özmen 2009). Studies from developed countries have mainly addressed three areas: conceptual change, skills development and content. Little is known about the effectiveness of computer simulations in developing countries. Available research indicates that computer simulations may bridge the gap between the concrete and the abstract world (Mintz 1993). Gokhale (1996) believes that these virtual experiences could provide the learner with an opportunity to learn by doing. Furthermore, Gokhale supports the

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findings of Menn (1993) who stated that learners retained 90% of what they had learned using computer simulations. The concretisation of objects, atoms, molecules and bacteria, for example, makes learning meaningful and appealing to real life situations. Learners can test theories by developing alternative realities which may greatly facilitate the mastery of difficult concepts; a case in point is the relation between distance, motion and time (Mintz 1993). Moreover, educators have positive attitudes towards using computers to improve their teaching pedagogy (Govender and Maistry 2012). It is also reported that physical (manual) experiments as well as computer simulations experiments support and complement each other in teaching and learning (Balakrishnan and Woods 2013).

In the case of Uganda, chemistry is one of the compulsory science subjects offered at Ordinary Secondary Level (O-level). The O-level is a four year study after primary seven and it is at this level that chemistry is first introduced as a separate subject. For over a decade, learners have performed poorly in chemistry in the Uganda Certificate of Education (UCE), also called 'O-level' examination (Ministry of Education and Sports 2006). The poor performance may partly be due to the manner in which chemistry is taught. Many learners experience difficulties when learning abstract chemistry concepts because the concepts are taught at a theoretical level with no visual mental representations (Gabel 1999). Consequently, learners fail to cognate concepts and therefore develop a negative attitude towards chemistry. These attitudes may account for the reduced number of learners studying chemistry after the mandatory O-level, when compared to other subjects. Computer simulations are seen as a possible intervention which could improve the teaching and learning of school chemistry as well improve learners' attitudes towards chemistry.

Objectives

The four objectives of this study were to: 1) determine learners' content knowledge prior to the formal teaching of chemical bonding; 2) compare the achievements of learners from the experimental group (EG) and control group (CG); 3) compare the performance of boys and girls in the EG in order to determine if com-

puter simulations discriminated against gender; and 4) compare experimental group (EG) and control group (CG) learners' attitudes towards chemistry after the teaching session.

Hypotheses

In addition to the above objectives, the following hypotheses were tested:

1. There is no statistically significant difference between the performance of learners in the EG and the CG in the pre-test.
2. There is no statistically significant difference between the achievements of learners in the EG and the CG in the post-test.
3. There are no statistically significant differences between the achievements of boys and girls in the EG.
4. Learners from (EG) will have positive attitudes towards science, but not those from (CG).

II. METHODOLOGY

Study Design

The study employed mainly a quasi-experimental design involving two groups: one whole class was assigned the EG and the other the CG. This design was informed by similar studies in other disciplines elsewhere in the world (Bourque and Carlson 1987; Thomas and Emereole 2002); the difference being that this study is conducted in the developing world. The EG was exposed to learning activities integrated with computer simulations, while the CG used traditional instruction where experiments were physically (manually) done without computer simulations. Comparisons of the performances of the learners were drawn by comparing the responses of the learners in the two groups.

Population and Sample

This study was conducted in a co-educational school with a population of over 2000 learners, of which 1500 were enrolled for O-level from senior one to four. The population of the study included five senior three classes each with an average of 65 learners making a total of about 325. Senior three as a class was chosen because chemical bonding is taught at this level according to the secondary school curriculum. Of the

five classes, only two classes (115 learners) participated in the study. One class was assigned to the EG with 58 learners (40 boys: 18 girls), while the other class consisted of 57 learners (36 boys: 21 girls).

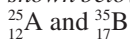
Research Instruments

Data were collected using an achievement test and an interview guide. The achievement test was administered by the second researcher as a pre-test and subsequently as a post-test. Questions in the post-test were the same like those used in the pre-test, however questions in the post-test were numbered differently to avoid recognition. The pre-test assessed the learners' prior knowledge of chemical bonding for both the EG and CG and the post-test assessed the learners' understanding of concepts after instruction. An interview guide of open-ended questions was then used to collect detailed information from 20 selected learners regarding the course and to gauge their attitudes towards chemistry.

The content validity of the researcher made test was established by matching the test items with the subject matter outlined in the Ugandan chemistry O-level teaching syllabus. The appropriateness of the options provided for each item was checked by three independent reviewers and suggestions were incorporated in the final version which consisted of 30 questions. Two experts in science education checked for face validity in the interview guide and the necessary changes were effected before conducting the interviews. To establish reliability, the achievement test was piloted to 20 learners in another school within the same district and a Cronbach Alpha of 0.81 was obtained and this was considered to be acceptable. A few questions from 30 questions used in the achievement test and the interview guide of 7 questions are portrayed below:

Exemplar Achievement Test

11. Element *a* and *b* can be represented as shown below.



The bond formed between A and B is

- (a) Covalent (b) Metallic (c) Ionic (d) Dative

19. Which one of the following is an electrovalent compound?

- (a) Calcium oxide (b) Sulphur dioxide (c) Hydrogen chloride (d) Phosphorous III chloride

20. The atomic numbers of elements *x* and *y* are 12 and 17 respectively. the formula of the compounds formed between *x* and *y* is

- (a) XY_2 (b) XY_3 (c) X_3Y (d) X^2Y (e) X_1Y

27. Which one of the following compounds exhibits an ionic bond?

- (a) SO_2 (b) FeCl_3 (c) NH_3 (d) CO_2

28. Which one of the following is an example of a compound having a covalent bond?

- (a) ZnO (b) CuS (c) CO_2 (d) FeCl_3 .

Interview Schedule

Think About the Lessons You Have had for Chemical Bonding:

- (i) What concepts did you like most?
- (ii) What concepts did you like least?
- (iii) How best can chemical bonding concepts be taught to make them easy for learning?
- (iv) Did you use computer simulations in the chemical bonding lesson?
- (v) If yes, what is your assessment of the lesson?
- (vi) If not, do you think that using computer simulations could help you to understand chemical bonding better?
- (vii) In your own view, can a computer make difficult concepts easy to understand? Give reasons for your answer.

Research Procedure

After obtaining permission from school administrators to conduct the study, the pre-test was administered to both EG and CG, followed by lessons about chemical bonding for a period of three weeks. The EG was taught using a combination of practical activities where learners follow instructions to confirm a known content and handled apparatus manually and computer simulations. Simulation included different bonded compounds: ionic and covalent bonding as well as transfer of electrons using different examples (Table 1). By incorporating computer simulations in the teaching of chemical bonding, the researchers presupposed that simulations would impact on the learners' learning in the following ways: 1) Develop learners' ability to break down the complex and abstract structure of an atom without losing sight of the

behaviour of electrons in the atom; 2) resolve any misconceptions that the learners might have about chemical bonding and help them to develop clear concepts about electrons in an atom; and 3) enhance learners' conceptual understanding. On the other hand, CG was taught using traditional approach where learners read hard copies and followed instructions to do activities and handled apparatus manually but no computer simulations were used. Teaching lasted for three weeks and there were two lessons of 80 minutes each every week (Table 1).

Table 1: Teaching schedule for experimental group

<i>Lessons</i>	<i>Lesson content</i>	<i>Duration (min)</i>
1 st	Chemical bonding as a force in chemical union: Activity – show the structure of the atom to bring out reason for bonding.	80
2 nd	Types of chemical bonding: Activity – display different bonded compounds.	80
3 rd	Ionic bonding as transfer of electrons: Activity – show transfer of electrons using different examples.	80
4 th	Products of ionic bonding: Activity – show ionic compound	80
5 th	Covalent bonding as sharing of electrons by atoms: Activity – show how electrons are shared using different examples.	80
6 th	Compare the two types of bonds: Activity – show the different product species of both ionic and covalent bonding.	80

Table 1 shows the content taught in each of the lessons, the activity that involved computer simulations, and the lesson duration. The first lessons were also used to introduce learners to the new teaching approach. After three weeks of teaching, a post-test was administered to assess learners' understanding of chemical bonding.

Six learners in each group shared a computer during the lesson and one of the researchers took the lead by giving instructions on how to access an activity, punctuated with explanations. In the CG learners were organised into small groups consisting of six learners per group in order to answer questions and were taught for three weeks like the EG except they used traditional only hands-on (manual) activities with no computer simulations. During instruction, hard copy

pictures on worksheets learning materials such as diagrams and models were used so that learners could reproduce them if required in an examination. There was no conceptual emphasis placed on understanding complex bonding in chemistry. Tape recorded interviews of 20 to 25 minutes per learner were conducted using 10 learners from the EG and 10 learners from the CG.

Data Analysis

The quantitative data collected were analysed using Statistical Package for Social Scientists (SPSS) version 17. Both descriptive statistics (mean and standard deviation) and inferential statistics (Analysis of Covariance-ANCOVA, Mann Whitney U-test) were used to analyse the data. Analysis of Covariance (ANCOVA) using pre-test scores as a covariate to statistically control the initial group differences was used to show any changes after the intervention. The effect size and Cohen's *d* were calculated to obtain the mean of the post-test for both the EG and the CG. Further analysis was done using a Mann-Whitney U-test to compare the level of chemical bonding concepts before instruction and the achievement of learners in the EG and the CG and also to determine if there were any differences in achievements between boys and girls in the EG. Data from interviews were analysed thematically using Braun and Clarke (2006) approach where texts were read and re-read to de-contextualize bits of information from primary data. Information was grouped into similar, dissimilar components and later re-examined against the purpose of study in order to generate themes.

III. RESULTS

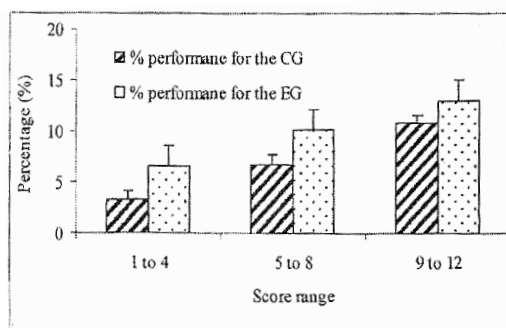
The overall scores of the pre-test for the EG were (mean 8.3 ± 2.3 SD) and scores for the CG were (mean 6.9 ± 1.8 SD), which were not significantly different using a Mann Whitney U-test ($U = 1415$, $P > 0.05$). These scores were very low, ranging between 5 and 12%, suggesting that both groups had very little knowledge of chemical bonding (Fig. 1).

Figure 1 indicates 25% more scores in the range of 9-12 marks for the EG than for the CG. The CG dominated with 79% in the ranges of 1-4 and 5-8 compared to 61% with ranges of 5-

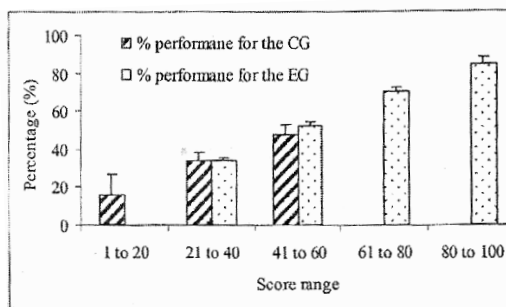
Table 2: Results of Analysis of Covariance (ANCOVA) for the pre- and post-tests using the pre-test as a covariate (*Significant at $p < 0.05$)

Source	Type III sum of squares	df	Mean square	F	Sig.
Corrected Model	4946.415 ^a	2	2473.207	15.720	0.000*
Intercept	18455.672	1	18455.672	117.307	0.000
Pre-test	4.129	1	4.129	.026	0.872
Post-test	4565.025	1	4565.025	29.016	0.000*
Error	17148.693	109	157.327		
Total	273088.000	112			
Corrected Total	22095.107	111			

a. R Squared = 0.224 (Adjusted R Squared = 0.210)

**Fig. 1. Comparison of learners' performance in a pre-test for the EG and CG (Bar represent SD)**

8 and 9-12 for the EG. Scores from the pre- and post-tests for the EG and the CG were (mean 54.0 ± 1.3 SD) and (mean 40.5 ± 10.8 SD) respectively and these scores were significantly different ($U = 56.5$, $P < 0.05$) (Fig. 2).

**Fig. 2. Comparison of learners' performance in a pre-test for the EG and CG (Bar represent SD)**

Results presented in Figure 2 portray varied performances between the CG and EG. The EG had 5% of its learners in the 81-100 range as opposed to none from the CG. In the EG, scores for the majority of learners (60%) ranged between 40 and 60, whereas over 50% of the learners in the CG scored less than 40%. The achieve-

ments of boys were lower (mean 47.18 ± 8.84 SD) than those of the girls (mean 68.94 ± 9.51 SD). These means were statistically significant ($U = 3.0.5$, $P < 0.05$) in favour of girls with upper scores ranging between 80 and 88, while none of the boys scored in that range. The calculated effect size was 0.5 and the Cohen d was 0.2.

ANCOVA was used to determine the effect of intervention (computer simulation) and the results are presented in Table 2.

In-depth Analysis of Learners' Learning When Exposed to Computer Simulations

In addition to comparing the achievement of the EG and the CG, the researchers examined the extent to which learning occurs when learners are exposed to computer simulations. This was carried out by categorising items in the achievement tests into four levels of the cognitive domain, namely; knowledge, comprehension, application and analysis. Learners' answers were analysed further to establish which of the items in the achievement tests were correctly answered by learners from both the EG and the CG. Results in Table 3 indicate that the achievements of the EG and the CG differ with regards to different learning skills.

Table 3: Learners' achievement in the different cognitive levels

Learning ability tested	Item number in the achievement test	Scores in percentages	
		Control	Experimental
Knowledge	1, 2, 3, 4, 5, 7, 8, 21, 22	53.3	69.9
Comprehension	9, 10, 12, 13, 15, 16, 17, 19	42.3	51.7
Application	20, 25, 26, 29, 30	38.7	37.9
Analysis	6, 11, 14, 18, 23, 27, 28	30.7	39.3

In addition to the achievement test, which was used to assess learners' knowledge about chemical bonding, an interview guide was administered to 20 learners after the post-test in order to solicit their opinions about the use of hands-on (manual) activities only as utilised in the CG, as opposed to the use of hands-on (manual) activities in addition to computer simulations as utilised in the EG. Three themes reflection, perceptions and convictions were identified from interview with EG and one or two quotations are presented in each of them here below:

Theme 1 (Reflection)

One of the questions in the interview guide required learners to reflect on the lessons and to state what concepts they liked most about chemical bonding. The vast majority of the learners (> 80%) reported that they liked the concept of sharing electrons between atoms, the transfer of electrons and the movement of electrons around the nuclei of atoms. For instance, one learner commented that: *with a computer, electrons are seen clearly when moving from one point to another.*

This comment was made in response to the experience of the students with computer simulations, clearly demonstrating how the electrons moved around the nucleus and from one atom to another, instead of teachers just telling learners about these movements as would be the case if computer simulations were not integrated in the teaching and learning process.

Theme 2 (Perceptions)

With regard to the least liked concepts of chemical bonding, the majority of the learners indicated dative and metallic bonding, and the properties of compounds formed during chemical bonding. This is what they had to say about dative and metallic bonding:

Dative and metallic bonding was perceived as being complex to imagine, the use of simulations has shown it in such a manner that most of us now can visualize the electrons moving around and being accepted by one group of atoms in the case of dative.... Also, the lining up of electrons in a metallic bonding was dramatically shown in the simulations and this we will never forget!

Theme 3 (Conviction)

Learners were asked to explain if and how a computer could make difficult concepts easy to understand. In their responses, the majority of the learners concurred that a computer could make difficult concepts simple and easier to understand. They also explained that the manner in which a computer presents concepts is fascinating and because of its multi-functionality it can combine sound and visual aspects. Learners further asserted that by adding graphics to text the computer is able to eliminate the abstractness of concepts and present a virtual reality, which makes complex concepts seem simple. They remarked that:

The computer uses its artificial "intelligence" to perform so many activities in a very short time. Computers are very wonderful because they perform many things at the same time... and computers are very exciting because you can visibly see the pictures on the screen as if the teacher is practically carrying out an experiment in the laboratory.

In the case of the CG, only one theme was identified: chemical bonding was difficult. All the learners indicated that chemical bonding was difficult to understand. Finally, learners of the CG were convinced that chemical bonding was boring and that there was no way in which it could be easily understood.

IV. DISCUSSION

The objective of this study was to investigate learners' achievements when using computer simulations in addition to hands-on (manual) activities and to compare them with the achievements of learners who used only hands-on (manual) activities during the teaching of chemical bonding. Since the learners' understanding of chemical bonding concepts was established from a pre-test, which was administered to both the EG and CG, any difference in achievement should be accounted to the computer simulations, which were only utilised in the EG. Results show that there was no statistically significant difference between the performance of the EG and the CG in the pre-test ($U = 1415$, $P > 0.05$) (Fig. 1), implying that the two groups were similar. Therefore, Hypothesis 1 arguing that there is no statistically significant difference between the achievements of the EG and

the CG in the pre-test is accepted. In terms of knowledge both groups had very little knowledge about chemical bonding because none of the learners scored above 12%. On the other hand, since none of the learners scored 0% it may imply that all the learners had some rudimentary knowledge about chemical bonding. This was possibly because many learners had studied atoms and molecules as well as the Periodic Table prior to the pre-test, suggesting that the timing and sequencing was perfect for introducing chemical bonding. Sequencing has been reported to affect achievement in science (Park et al. 2009). For instance, the majority of the learners both in the EG and the CG were able to tell that chemical bonding is a chemical and not a physical combination of two or more atoms. This knowledge is likely to have been constructed during lower classes on topics such as the Periodic Table, and physical and chemical changes.

Although it was expected that both groups would equally benefit, this was not the case because the EG benefitted more than the CG in the post-test (ANCOVA, $p < 0.05$) (Table 1), suggesting that computer simulation activities may have played a significant role. Learners from the EG who were using computer simulations in addition to hands-on (manual) activities outperformed learners from the CG who were using hands-on (manual) activities only (Fig. 2). The post-test scores for the majority ranged from (40-60) for the EG and were superior when compared to those of the CG that ranged from (20-60). More notably are the scores of the EG in the ranges of (60-80) and (80-100) and the absence of scores from the CG in these two ranges. The gain in the EG can only be attributed to computer simulations since this was the only additional activity not used in the CG. Our findings are in agreement with Rutten et al. (2012) who reported learners' gains of up to a maximum effect size of 1.54. Results from a Mann-Whitney U-test ($U = 1415$, $P > 0.05$) show that the achievements of the EG is statistically different from that of the CG. Thus, these results strongly suggest that the use of computer simulations in teaching chemical bonding could improve achievements, especially, in the distinction range (75-100) (Table 2). The effect size of 0.5 obtained is greater than (> 0.35) which is a large gain according to Cohen (1988) and it is in favour of the EG. Therefore, Hypothesis 2

arguing that there is no difference between the EG using computer simulations as an addition to laboratory hands-on (manual) activities and the CG using only traditional laboratory hands-on (manual) activities, is rejected. These results are not surprising because simulation in addition to traditional laboratory hands-on (manual) teaching has been reported in developed countries to have equally improved the achievements of learners (Bell and Trundle 2008; Trundle and Bell 2010, Rutten et al. 2012) and computer simulations seem to "provide near-authentic environment, context and situation for task-based learning" (Chen et al. 2013: 172) and that simulated experiments provide an environment that is conducive to learning (Balakrishnan and Woods 2013). In addition, a Mann Whitney U-test ($U = 3.0.5$, $P < 0.05$) illustrates that girls in the EG performed equally well like the boys their counterparts. Therefore, Hypothesis 3 arguing that there is no difference in achievement between girls and boys who were taught using computer simulations in the EG is accepted. These results suggest that computer simulations did not discriminate against gender at least in this study.

During the interviews, learners were asked to suggest how chemistry concepts could best be taught in order to simplify learning. In response, all the learners from the EG indicated that chemistry should be taught using laboratory hands-on (manual) activities in addition to computer simulations. Overall learner assessments suggested that lessons were very interesting, exciting and educative. This could partly explain why, with the exception of questions on application, learners in the EG outperformed those from the CG in questions regarding knowledge, 69.9%; comprehension, 51.7%; and analysis, 39.3% (Table 3). The comments of the learners clearly indicate that computer simulations are invaluable instructional materials in the teaching and learning process, thus minimising learners' negative attitudes towards teaching and learning chemistry. These findings are in agreement with earlier studies where computer simulations were found to significantly improve the achievements of learners (Akpan and Andre 2000; Barnea and Dori 1999; Donnelly et al. 2012) and to develop content knowledge (Sherwood and Hasselbring 1985/86; Scalise et al. 2011). Learners exposed to computer simulations performed best in skills of recall, comprehension and analysis when compared to those

taught without computer simulations, suggesting the effectiveness of computer simulations. While a teacher may be subtle and complex in his or her explanations of certain facts, computer simulations provide simplified explanations that are easy to follow. Owing to the fact that every step in a simulation is explained in a summary, computer simulations enhance the recall process, comprehension and analysis of chemical bonding concepts. Computer simulations yield interesting results in a very short space of time. As a result, learners exposed to computer simulations are highly motivated, pay much attention to detail and learn better. It has also been noted that the youth interact easily with computers. Thus, they find it easier to understand computer simulated programs than instructions from regular teachers. Similarly, in certain instances, learners fail to understand certain concepts because of fears or prejudices they have with regards to individual teachers. With computer simulations, this problem is minimised, leading to better understanding. On the other hand, all learners from the CG, who did not use computer simulations in their chemistry lessons, indicated that chemical bonding concepts were difficult to learn and at best boring. It is no wonder that many of them developed a negative attitude towards chemistry.

V. CONCLUSION

The greatest contribution of the computer simulations was the enhancement of learners' understanding of abstract chemistry concepts. Practically, computer simulations allowed learners to visualise chemical reactions at a microscopic level. The EG had a better understanding of chemical bonding concepts when compared to traditional hands-on (manual or laboratory apparatus handling) teaching. Computer simulations helped learners to create imaginable representations of chemical reactions much better than traditional teaching did. Thus, computer simulations in conjunction with verbal narration provided by the teacher allowed learners to visualise the movements of electrons and thereby created a better understanding of chemical bonding concepts.

VI. RECOMMENDATIONS

Although a small sample was used in this study, the information gained is invaluable and

further studies with larger samples to validate these findings are highly recommended. Also, studies using subjects other than science can use simulation to confirm or refute our findings.

REFERENCES

- Akpan JP, Andre T 2000. Using a computer simulation before dissection to help students learn anatomy. *J Comp Math Sci Teach*, 19(3): 297-313.
- Balakrishnan B, Woods PC 2013. A comparative study on real lab and simulation lab in communication engineering from students' perspectives *Eur J Eng Educ*, 38(2): 159-171.
- Govender DW, Maistry SM 2012. Exploring teachers' propensity for technology adoption in business education. *J Soc Sci*, 3(2): 193-202.
- Barnea N Dori YJ 1999. High-school chemistry students' performance and gender differences in a computerized molecular modeling learning environment. *J Sci Educ Tech*, 8(4): 257-271.
- Bell RL, Trundle KC 2008. The use of a computer simulation to promote scientific conceptions of moon phases. *J Res Sci Teach*, 45: 346-372.
- Bilan B 1992. Computer Simulations: An Integrated Tool. Paper presented at the SAGE 6th Canadian Symposium, The University of Calgary.
- Braun V, Clarke V 2006. Using thematic analysis in psychology. *Qual Res Psychol*, 3: 77-101.
- Bourque DR, Carlson GR 1987. Hands-on versus computer simulation methods in chemistry. *J Chem Educ*, 64(3): 232-234.
- Cohen J 1988. *Statistical Power Analysis for the Behavioral Sciences*. 2nd Edition. New Jersey: Lawrence Erlbaum Associates.
- Chen G D, Nurkhamid N, Wang CY, Yang SY, Lu WY, Chang CK 2013. Digital learning playground: Supporting authentic learning experiences in the classroom. *Int Learn Environ*, 38(2): 159-171.
- Chung C, Newman KSS 2000. Computer Animations and Simulations in General Chemistry. From <<http://www.science.uwaterloo.ca/~cchieh/cact/trios/simulation.html>> (Retrieved on March 5, 2012).
- Donnelly DO, Reilly J, McGarr O 2012. Enhancing the student experiment experience: Visible science inquiry through a virtual chemistry. *Res Sci Educ*, DOI 10.1007/s11165-1012-9322-1.
- Gabel D 1999. Improving teaching and learning through chemistry education research: A look to the future. *J Chem Educ*, 76(4): 548-554.
- Gokhale AA 1996. Effectiveness of computer simulation for enhancing higher order thinking. *J Indust Teach Educ*, 33(4): 36-46.
- Howe C, Devine A, Tavares JT 2013. Supporting conceptual change in school science: A possible role for tacit understanding. *Int J Sci Educ*, 35(5): 864-883.
- Huppert J, Lomask SM, Lazarowitz R 2002. Computer simulations in the high school: Students' cognitive stages, science process skills and academic achievement in microbiology. *Int J Sci Educ*, 24(8): 803-821.
- Kaheru S J, Mpeta, M, Kriek J 2011. The use of interactive computer simulations with regard to access to Education – a social justice issue. *J Educ Stud*, 10(2): 89-106.
- Menn D 1993. Multimedia in education. *PC World*, M52-M60.

- Michael KY 2001. The effect of a computer simulation activity versus a hands-on activity on product creativity in technology education. *J Tech Educ*, 13(1): 31-43.
- Mintz R 1993. Computerized simulations as an inquiry tool. *Sch Sci Math*, 93(2): 76-80.
- Ministry of Education and Sports 2006. Uganda Educational Statistics Abstract, Volume 1. From <<http://library.umu.ac.ug:81/cgi-bin/koha/opac-detail.pl?biblio number=28131>> (Retrieved on May 5, 2011).
- Özmen H, Demircioğlu H, Demircioğlu G 2009. The effects of conceptual change texts accompanied with animations on overcoming 11th grade students' alternative conceptions of chemical bonding. *Comp and Educ*, 52(3): 681-695.
- Park SI, Lee G, Kim M 2009. Do students benefit equally from incentive computer simulations regardless of prior knowledge levels? *Comp and Educ*, 52(2): 649-655.
- Quellmalz E, Timms M, Silberglitt M, Buckley B 2012. Science assessment for all: Integrating science simulations into balanced state science assessment systems. *J of Res Sci Teach*, 49(3): 363-393.
- Rutten N, van Joolingen WR, van der Veen JT 2012. The learning effect of computer simulations in science education. *Comp and Educ*, 58(1): 136-153.
- Scalise K, Timms M, Moorjani A, Clark L, Holtermann K, Irvin P 2011. Student learning in science simulations: Design features that promote gains. *J Res Sci Teach*, 48(9): 1050-1078.
- Sherwood RD, Hasselbring T 1985/86. A comparison of student achievement across three methods of presentation of a computer-based science simulation. *Comp in the Sch*, 2(4): 43-50.
- Strangman N, Hall T 2003. Virtual Reality/Simulations. Wakefield, MA: National Center Accessing the General Curriculum. From <http://www.cast.org/publications/ncac/ncac_vr.html> (Retrieved on September 13, 2008).
- Thomas PY, Emereole HU 2002. Effect of computer-based instruction on performance in physics. *Afri J Res Math, Sci Tech Educ*, 6: 97-112.
- Trundle KC, Bell RL 2010. The use of a computer simulation to promote conceptual change: A quasi-experimental study. *Com and Educ*, 54(4): 1078-1088.