UNIVERSITY OF EDUCATION, WINNEBA

THE INFLUENCE OF COMPUTER SIMULATION INSTRUCTIONAL METHODS ON STUDENTS' PERFORMANCE IN CHEMICAL BONDING

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2016

UNIVERSITY OF EDUCATION, WINNEBA

DEPARTMENT OF SCIENCE EDUCATION

THE INFLUENCE OF COMPUTER SIMULATION INSTRUCTIONAL PACKAGES ON STUDENTS' PERFORMANCE IN CHEMICAL BONDING

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A DISSERTATION PRESENTED TO THE DEPARTMENT OF SCIENCE EDUCATION, FACULTY OF SCIENCE EDUCATION, UNIVERSITY OF EDUCATION, WINNEBA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER DEGREE IN SCIENCE EDUCATION (M.ED SCIENCE).

OCTOBER, 2016

DECLARATION

CANDIDATES DECLARATION

I, ALEXANDER NTI KANI, hereby declare that except references to other people's work which have been duly cited and acknowledged, this thesis is the result of my own work and that no part of it has been presented for another dissertation in the University or elsewhere.

ALEXANDER NTI KANI …………………….. OCTOBER, 2016

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SUPERVISOR'S DECLARATION

I, **Ishmael K. Anderson** hereby declare that the preparation and presentation of this thesis was supervised by me in accordance with the guideline on supervision of thesis laid down by the University of Education, Winneba.

Dr. ISHMAEL K. ANDERSON …………....……….. OCTOBER, 2016

SUPERVISOR'S NAME SIGNATURE DATE

ACKNOWLEDGEMENTS

This work couldn’t have been possible without the help and assistance of some people who devoted their time, resource among other things to see me through up to this time.

A Special word of thanks goes to my invaluable supervisor; Dr. Mrs. Vida Eshun and Dr Anderson. I am forever grateful to them for their supervision and directions.

I am most grateful to my mother, Beatrice Ntiriwaa Campbell (Obaa Yaa), for her invaluable support and assistance during the course of my studies.

Am thankful to Ps. Prof. Yaw Afari Ankomah (IEPA-UCC) for his prayers, wise counsel and encouragement to take up this challenge when it was evident that my ability to complete this professional program in Education could open up several avenues for me in the teaching profession.

Special thanks to all Chemistry masters and students in the following schools; Anglican Senior High School, T. I Ahmadiyya Senior High School, Armed Forces Senior High School, Osie Tutu Senior High School, Kumasi Senior High School, and St Louis Senior High School, for their help in one way or the other to carry out this study in Kumasi.

Many thanks to Mrs Kate Yeboah-Appiagyei and Ms. Esther Sam-Abandon-Sam, of Valley View University, Techniman Campus, who volunteered to proofread this dissertation for me.

My outmost thanks to Elder Emanuel Buabeng Berko and Family and all my friends, including Gabriel Ayitor Seyram Kofi (Abura Dunkwa Municipal Assembly), who was there for me when the going went tough and I wanted to give up. I appreciate your financial support.

I am also thankful to Mr Alex Conduah, Mr Agyemang (Agyengo), Mr Francis Kusi Sarpong (SARPS), my colleague Chemistry masters Mr Dovi, Mr Andoh and Mr Eugene (all of Anglican Senior High School, Kumasi) whose efforts and assistance helped to verify and standardise the research instruments used in this research.

DEDICATION

I wholeheartedly dedicate this work to my Lord and God, my mother, Beatrice Ntiriwaa Campbell, my father Rudolf Kwabena Kani, my lovely Wife, Charlotte Acheampong, the very good people of Akyem Abuakwa Kingdom and all well-meaning Citizens who are working tirelessly to improve upon the life of the ordinary citizens of our motherland.

LIST OF ABBREVIATIONS

CBAT: Chemical Bonding Achievement Test

CIA: Computer Assisted Instruction

CRDD: Curriculum Research and Development Division

GES: Ghana Education Service

ICT: Information, Communication Technology

MoE: Ministry of Education

SHS: Senior High School

SKCBT: Students' Knowledge of Chemical Bonding Test

SSSCE: Senior Secondary School Certificate Examination

VSEPR: Valance Shell Electron Pair Repulsion

WAEC: West African Examination Council

WASSCE: West African Senior School Certificate Examination

TABLE OF CONTENT

List of Tables

List of Figures

List of Abbreviations

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ABSTRACT

Growth to a worldwide scale in the 21st century has ensued innovative ways of teaching and learning. The traditional method of teaching and learning of science is fast losing its acceptance and impact in the educational sector. Computers have become increasingly important among science educators as they play important roles during the instruction of students in the science classroom. To demonstrate conditions of conceptual change in science learning, simulation-based environments are deemed to be appropriate. This study therefore sought to investigate the influence of Computer Simulation Instructional methods on Students' performance in Chemical Bonding using quasi-experimental research approach. The study was delimited to 180 second-year science students at the SHS level from six schools in Ashanti Region. The main instruments used were researcher-created Students' Knowledge of Chemical Bonding Test (SKCBT) and Chemical Bonding Achievement Test (CBAT), supported with Pre-test Students Questionnaire. The tests and the questionnaire were subjected to content validation and reliability test. Data collected were analysed using SPSS Version 20 and Microsoft Excel. The study revealed a significant ($p<0.05$) improvement in students' performance and cognitive understanding with the intervention. This was evident in the mean score of the experimental group, which increased from 18.27 (±2.62) to 24.24 (±2.38) and the mean difference was found to be significant (p-value<0.05). The degree of significant improvement was found to be 19.9%. There was no gender disparity in the performance of students. Notwithstanding the general abstractness of chemical bonding, majority of students were found to have interest in the subject. It is therefore recommended that curriculum innovation should be done to incorporate computer-assisted instruction in the science curriculum at the SHS level. Funds should also be made available for the purchase of such resources and the training of teachers in its usage.

CHAPTER ONE

INTRODUCTION

1.1 Overview

This chapter discusses the introduction to the study. It includes the background of the study, statement of the problem and purpose of the study, objectives, research questions that guided the study, research hypotheses and the null hypotheses that were formulated and tested in the study. It further discusses the significance, delimitations, limitations and operational definitions of terms used in the study.

1.2 Background to the Study

Globalization in the 21st century has brought new developments to the teaching and learning of science. It is now being recognized that there are better ways to learn science than through the traditional methods of instruction (Wood & Gentile, 2003).

Since the introduction of SSSCE in 1993 and WASSCE in 2006 by the Ministry of Education (MoE) in Ghana, most science students in the Senior High Schools have continuously performed poorly in Chemistry (Offei-Koranteng, 2013).

Empirical evidence available and obtained through the work of the Researcher as a Chemistry Teacher and a Chemistry Assistant Examiner for the West African Examinations Council (WAEC) at the Senior High School (SHS) level, suggests that most students perform poorly in chemistry because they have difficulty with learning and understanding some chemistry concepts such as chemical bonding. WAEC (2008) confirmed it when it revealed that only a few students who took part in the May/June 2008

WASSCE attempted questions involving chemical bonding and organic chemistry. This may be because some chemistry concepts are taught abstractly, making some of the concepts seem complex, confusing, and therefore difficult for students to comprehend. According to Njoku (2007) and Jimoh (2004), the performance of students in chemistry at the secondary school in West Africa has been poor and deplorable over the years. Analysis of students' performance in science at SSCE level as noted by Njoku (2007) revealed that between 1980 and 1991, the annual average pass rate at credit level (grade 1-6) in chemistry was 15.41%, while the absolute failure rate (grade 9) was 61.82%.

Farounbi (1998) reported that students tend to understand and recall what they see more than what they hear as a result of using laboratories in the teaching and learning of science. Students have problems learning some chemistry concepts meaningfully and therefore, resort to memorizing these concepts and reproducing them during exams. Additionally, a research by Lagowski (1990) on student knowledge retention, he reported that students usually retain 10% of what they read; 26% of what they hear; 30% of what they see; 50% of what they see and hear; 70% of what they say; 90% of something they say while they are doing a task.

According to Srisawasdi & Panjaburee (2015), Computers have become increasingly important among science educators, and play important roles during the instruction of students in the classroom and science laboratory. In their opinion, the introduction of computers as an instructional instrument has helped improved teaching and learning. Chen *et al.,* (2013), posited that computer simulation-based learning are considered as appropriate for manifesting conditions of conceptual change in science learning. Cook (2006) and Wu & Shah (2004) reported on visual-aid learning with simulations that, the visualizations (from the computer simulations) facilitated the integration of cognitively new knowledge with existing knowledge, which are important components of learning. This comes to substantiate the fact that computer stimulations in teaching and learning of chemistry will help students to probably understand better whiles being able to recollect the various concepts taught. This could be because the student is enabled to visualize the concepts as the simulations are done.

Akpan (2001) observed that the use of computer simulation instructional packages to enhance teaching and learning in the science classroom has become the focus of most recent research studies. A number of researchers have recommended the effect of computer simulations instructional packages as tools for classroom instruction. For example, Sahin (2006) suggested that computer simulations are good supplementary tools for classroom instruction and in science laboratories, as they give students the opportunity to observe a real world experience and interact with it. Computer simulations are also good tools to improve students' hypothesis construction, graphic interpretation and prediction skills. Akpan (2001); Akpan & Andre (2000); and Coleman (1998), have all reckoned that computer simulations can be used as extremely effective tools to help students understand difficult concepts.

It is therefore evident that the incorporation of computer simulations instructional packages in the teaching and learning processes would improve the understanding of learners. A study to measure the influence of Computer Simulation Instructional packages in the teaching and learning of complex and confusing chemistry concepts, like chemical bonding, in Ghanaian Senior High Schools (SHSs) is therefore exigent.

1.3 Statement of the Problem

The performance of Ghanaian students in the West African Senior Secondary Certificate Examination (WASSCE) in chemistry has been a worry for many stakeholders in the educational system for some years now. Empirical evidence available and obtained through the work of the Researcher as a Chemistry Teacher and a Chemistry Assistant Examiner for the West African Examinations Council (WAEC) at the Senior High School (SHS) level, suggests that most students perform poorly in chemistry because they have difficulty with learning and understanding some chemistry concepts (WAEC, 2008, 2006).

Incidentally, assessment of the examination scripts of seventy second-year chemistry students of Anglican Senior High School, during the end of the second term examination, 2015 (the term students were taught chemical bonding) indicated a similar observation as made by WAEC (2008). In the assessment it came to light that out of the 70 students, only 30 (42.9%) attempted answering questions involving chemical bonding. Out of these 30 students, only 12 (40%) correctly answered the questions as the remaining 18 (60%) had difficulties in defining covalent bond, ionic bond, distinguishing between the types of hybridization, explaining correctly the term hybridization among others. The casual assessment generally indicated that even though the students had been taught chemical bonding, there was a low performance in students' scores of chemical bonding (Field Data, 2016).

Some science students in the Senior High Schools in Ghana consider chemical bonding as a difficult part of the chemistry syllabus. This problem could have been compounded by the abstract nature in which it is taught and a probable didactic, using chalk-talk method with little or possibly no student involvement and the absence of instructional materials.

The incorporation of computer simulation instructional packages in the teaching and learning processes would improve the understanding of learners. This is because students will not have to imagine the concepts taught and their interconnections but rather, they would have the chance to visualize concepts. Simulations provide students with a very real experience (Hertel & Millis, 2002). The simulation thereby promotes a transfer of knowledge and helps with not only the education but also the application of a particular issue or concept. Ultimately, students learn how to think critically in a complex situation (Brumfield, 2005).

Although a number of studies have been conducted on the use of ICT in science education (Sert *et al.,* 2008; Çepni, *et al.,* 2006; Hogarth, *et al.*, 2006; Sahin, 2006; Trucano, 2005; Farounbi, 1998), very little is known about the effect of the incorporation of computer simulation instructional packages in the teaching and learning processes on students' performance in chemical bonding in Ghana. A study to investigate the effect of the incorporation of computer simulation instructional packages in the teaching and learning of chemical bonding in Ghanaian SHS students is therefore imperative.

1.4 Purpose of Study

The purpose of this study was to investigate the influence of Computer Simulation Instructional packages on Ghanaian SHS Students' performance in Chemical Bonding.

1.5 Specific Objectives of the Study

The objectives of the study were to:

1. determine the initial performance of students (experimental and control) in chemical bonding before the intervention.
2. determine the performance of the students (experimental and control) after the intervention.
3. investigate any differences in performance between students exposed to the intervention and their counterparts who were not exposed to the intervention.
4. identify any gender disparities in the performance of students exposed to the intervention.

1.6 Research Questions

The following research questions guided the study:

1. What is the initial performance of students (experimental and control) in chemical bonding before the intervention?
2. To what extent will the intervention influence the performance of the students in chemical bonding?

3. What is the difference in performance between students exposed to the intervention and those not exposed to the intervention in chemical bonding?
4. Will there be a statistically significant difference between performances by male and female students in the experimental group?

1.7 Research Hypotheses

The following were the research or alternative hypotheses for the study:

H_A 1: There is statistically significant difference between the initial performance of students in chemical bonding before the intervention.

H_A 2: The intervention will significantly improve the performance of students in chemical bonding?

H_A 3: There is statistically significant difference between the performance of male and female students exposed to the intervention.

1.8 Null Hypotheses

The following null hypotheses (H_o) would therefore be tested in this study:

Ho 1: There is no statistically significant difference between the initial performance of students in chemical bonding before the intervention.

Ho 2: The intervention will not significantly improve the performance of students in chemical bonding?

Ho 3: There is no statistically significant difference between the performance of male and female students in chemical bonding when exposed to the intervention.

1.9 Significance of the Study

Hogarth *et al.*, (2006), reported that there is enough evidence to demonstrate that computer simulation instructional packages can be used successfully to teach science ideas including scientific knowledge and approach. The study would therefore produce an empirical data that would report on the effect of the incorporation of computer simulation instructional package in the teaching and learning processes on the performance of SHS students in chemical bonding.

It was envisaged that the study would transform the teaching of chemistry from the use of only traditional instructional approach of lecture, discussion, demonstration and illustration into a situation where computer simulation instructional packages would be incorporated in the teaching and learning processes. This will lead to increased learning gains in chemistry for students, creating the opportunity for learners to develop their creativity, problem-solving abilities, communication skills and other higher-order thinking skills as reported by Trucano (2005). This will help to improve the teaching and learning of chemistry at the SHS level and help chemistry teachers in the schools involved in the study realize the importance of incorporating computer simulation instructional packages in the instructional process. This will further give a basis for possible suggestions to stakeholders to consider the idea of computer stimulations in the teaching and learning of science in Ghana.

1.10 Delimitations of the Study

The study was delimited to six (6) Senior High Schools in the Ashanti region. This study was specifically delimited to only SHS 2 Science students who offered Chemistry as an elective subject in the schools since they had been taught chemical bonding at the time of the research.

1.11 Limitations of the Study

The Researcher understands that all environments are inherently unique and does not claim that the findings of the study will necessarily be found in other environments if the study was to be replicated somewhere else. The following can be considered as limitations to the study, which there would affect the generalisability of the findings to a certain degree. The study was designed to focus on learning of chemical bonding by SHS 2 students. Thus, the findings may not be generalizable to cover the entire SHS elective chemistry syllabus.

Also, the study was intended to include all SHSs in the Ashanti Region but was conducted in only six SHSs in the Region, Anglican Senior High School, T. I Ahmadiyya Senior High School, Kumasi High School, Armed Forces Senior High School, Osei Tutu Senior High School and St Louis Senior High School, all in Ashanti Region of Ghana, which offer the science programme including elective chemistry. The findings may therefore not be generalized to cover all the SHSs in the Ashanti Region.

1.12 Operational Definition of Terms

Simulation: instructional methods used when real world experiences are either unavailable or undesirable. It can also be defined as the controlled representation of real world phenomena.

Intervention: exposing students to computer simulation instructional approach to the teaching and learning of chemical bonding.

Control Group: The group of students who were not exposed to the intervention (thus taught by traditional method of teaching).

Traditional method of teaching: Also known as the chalk and board method of teaching where the teacher is seen mostly to be lecturing. It is mostly teacher oriented and is characterized by less student participation where students' listen and make notes.

Experimental Group: It referred to the students who were taught with computer simulation Instructional methods.

1.12. Organization of the other Chapters

The other sections of this research report have been grouped under Chapter two, three, four and five. Chapter 2 provides an in-depth literature of the subject matter and all topical issues relating to the chemical bonding. Chapter 3 provides information on how the entire research was carried out, comprising of the research design, the sampling techniques, research instruments, data collection as well as how data gathered was analysed. Chapter four presents the results of the study guided by the research question in the determination of the influence of computer simulations in the teaching and learning of chemical bonding. Chapter five is devoted to the summary of the study, conclusions and suggestions for future studies.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter provides the literature that has been reviewed which focused on work done by researchers in related fields such as computer simulation, chemical bonding among others. The topical issues reviewed in the literature include the theoretical framework of the study, which discusses among others the theories of Jean Piaget upon which the study was hinged. The concept of computer simulations and the use of computer simulations in chemistry teaching have also been discussed in this chapter. Finally, Students' difficulties in understanding the concept of chemical bonding have been dealt with in the literature.

2.1 Theoretical Framework of the Study

Children construct their own knowledge through experiences gained by observing, exploring and performing in the real world. The constructivist approach to education centres on this claim. Jean Piaget's theory of cognitive development is the theoretical framework that underpins this study. The cognitive development of children toward formal thought could be facilitated through three cognitive processes, assimilation, accommodation and reorganization or equilibration (Piaget, 1954). This implies that when children assimilate, they perceive new objects and events according to their existing schemata (internal representations, mental models or cognitive structures). The mental models of children, formed by their prior knowledge and experience, therefore, control how they incorporate new experiences and new information into their minds. This may occur when the new experiences of children are aligned with their existing schemata or because of their failure to change a faulty understanding (Piaget, 1954). Sometimes, when children's experiences contradict their existing knowledge or schemata, they may change their perceptions of the experiences to fit their internal representations.

In Piaget's understanding, accommodation results as children reframe or modify their existing schemata or mental representations of the external world to fit their new experiences for learning to occur (Piaget, 1954). Thus, as children exercise existing mental structures in particular environmental situations, accommodation-motivating disequilibrium results and the children construct new mental structures to resolve the disequilibrium (Piaget, 1954). The state of disequilibrium and contradiction arising between the existing schemata and the more sophisticated mode of thought adopted by the new experience therefore, has to be resolved via equilibrium process.

Equilibration maintains the balance between always taking in new knowledge, and always assimilating knowledge with previously gained knowledge. Knowledge is therefore, not a mirror of the world but is created or 'constructed' from the individual's continuous revision and reorganisation of cognitive structures in conjunction with experience (Piaget, 1954). Thus in the view of Piaget, students are actively involved in the construction of their own knowledge. It is therefore, argued that knowledge is constructed through action and that children must continually reconstruct their own understanding of phenomena through active reflection on objects and events till they eventually achieve an adult's perspective.

Piaget therefore axiom that the process of intellectual and cognitive development is similar to a biological act, which is adaptation to environmental demands.

2.2 Traditional Teaching Methods in Science Education

According to Kinney & Robertson (2003), traditional instruction is teacher-centred and characterized by direct instruction. To them, direct instruction includes the presentation of material, thinking aloud by the teacher, guided practice, correction and feedback and modelling by the teacher. Brown (2003) added that in this system of teaching, the teacher plays the role of the expert imparting knowledge and decides what, when and how students should learn with all students studying the same topic at the same time. In a study by Grasha (1994), it was reported that most faculty members in the universities in America taught using teacher-centred mode of instruction assuming the role of expects, authority and model. This observation was not different from what Armington (2003) reported in a later study. There is always the tendency for teachers to use the same instructional methods with which they were taught and those they feel more comfortable with in their teaching career.

Some educators have difficulty with this type of teaching as it is suggested that the teacher is responsible for thinking and the students are just to memorize and recite. Hence, the teachers tend to focus on content, schedules and standards but not the needs of the students (Brown, 2003). Mahmood (2006) suggested that teachers who lecture during classroom instruction operate under the assumption that if they do not lecture they will lose control of the class and so they tend to view the students as empty pails waiting to be filled and themselves as the "sage on the stage". According to Brothen & Wambach (2000), some faculty members think that teaching means "Speaking aloud from the front of the classroom". They posited on their research on a developmental psychology course that lectures alone are inefficient means of pedagogy in this 21st century. Oni (2012) adumbrated that such learning mode tends to be passive and learners play little part in the teaching and learning process, which results in students playing a passive role, and their concentration fades away after 15 – 20 minutes. This directed instructional mode has its foundations embedded in the behavioural learning theory and is a popular technique in use for decades as an educational strategy in all institutions of higher learning (Mayes, 1993). The traditional method of teaching assumes that all students have similar levels of knowledge in the subject being taught and they absorb new material in a similar way (Marbach-Ad, Seal & Sokolove, 2001).

2.3 Concept of Computer Simulations

Simulation-based learning environments are considered as appropriate learning tools for manifesting conditions of conceptual change in science learning (Chen *et al*., 2013). Technology integration has become popular in education. Teachers are always looking for ways to effectively utilize technology tools in our classrooms. At its inception, technology in education meant bringing in computers for teachers to use and any available software that was available. As technology integration evolves in the classroom, we now have a wide variety of teaching tools available to help facilitate student learning. One such tool is simulations (Chen *et al*., 2013).

Simulations can be considered a variant of cognitive tools, that is, they allow students to test hypothesis and more generally "what-if" scenarios and enable learners to ground cognitive understanding of concepts (Thomas & Milligan, 2004). According to Thomas & Milligan (2004), simulations in this respect are compatible with a constructivists' view of education. Light & Mevarech (1992) pointed out that since the early 1980s there has been a growing interest in the potentialities of computers as facilitators of students learning. A simulation is an instructional strategy that offers the opportunity to learn in a realistic environment and practice problem solving skills without danger. Rothwell & Kazanas (1999) defined a simulation as an artificial representation of real conditions. According to Lee (1994), a simulation is a computer program in which it creates a set of things through the means of a programme and then relates them together through cause and effect relationship".

These instructional methods are used when real world experiences are either unavailable or undesirable. Computer-based instructional simulation is among the most powerful educational delivery method because computer-based instructional simulations provide situated, authentic form of practice, feedback about performances, depictions of how a device or system works, and a motivation for learning while avoiding physical danger and constraints.

2.4 Importance of Computer Simulations in Teaching and Learning

Newberry (1999) suggested that, the use of computer simulations in teaching and learning has helped to enhance a wide range of school outcomes, including academic achievements, cognitive processes, meta-cognitive skills, motivation toward learning, self-esteem and social development. This seems to indicate that computer simulation learning strategies have a positive influence on students' achievements.

Several advantages of instructional simulations have been identified. Among the advantages, simulations have the potential to do the following:

- ✓ work as a remedial process by producing change in the alternative conceptions held by learners (Bell & Trundle, 2008; Srisawasdi *et al*., 2013; Srisawasdi & Kroothkeaw, 2014; Srisawasdi & Sornkhatha 2014).
- ✓ improve the performance of gaining intuitive domain-specific knowledge, and promoting more qualitative knowledge than formalized knowledge (de Jong *et al*.,1998; Suits & Srisawasdi, 2013).
- ✓ help in achieving a more theoretical focus and coherent understanding of the concepts (Winberg & Berg, 2007).
- ✓ promote positive perception of science learning (Buyai & Srisawasdi, 2014; Pinatuwong & Srisawasdi, 2014).
- ✓ improve teaching aims and methods (Baillie & Percoco, 2000; Orrill, 2001 and Yeh, 2004).
- ✓ improve learning and practice (Mangan, 2003; Boyd & Jackson, 2004 and Turkle, 2004).
- ✓ motivate students (Baillie & Percoco, 2000; and Mitchell & Savill-Smith, 2004).

- ✓ save operational cost and time (Lederman & Niess, 1999; Mangan, 2003 and West & Graham, 2005).

Perkins *et al*., (2006), also stated that computer simulations allow students to make connections with everyday life experiences. As a result, effective use of computer simulations leads to improved learning outcomes as reported by Perkins *et al*., (2006), particularly when simulation outputs are visually realistic (Martinez *et al*., 2011).

2.5 Gender Issues in The Use of Computer Simulations in The Teaching and Learning of Science

Over the years, Gender issues have surfaced in students' academic performance without any concrete conclusion. Some researchers argue that there is a general imbalance students' performance with respect to computer usage in the learning environments. So it is not surprising that currently gender imbalance in technology is of concern for men and women, practitioners, policy makers and parents. Gender factors associated with the use of Computer Assisted Instruction (CAI) have been a subject of interest for some researchers since the 1990s.

Some studies (Danmole, 1998; Novak & Mosunda, 1991; Okeke & Ochuba, 1986) suggested that male students performed better than their female counterparts in biology, chemistry and physics. Other related studies (Kelly, 1978; Wonzencreaft, 1963) also posited that the females were better academically than their male counterparts with respect to academic performance in computerized science education. Another twist to these findings was the report of Bello (1990), which indicated that academic performance of science students was not influenced by their gender. The report by Spencer (2004) seem to agree with the findings of Bello (1990), where Spencer found no significant influence of gender on the achievement of college students in mathematics when they were exposed to mathematics courseware in online and traditional learning environment. However, female online learners were significantly less likely to complete the course compared to their traditional female counterparts or male online counterparts. Kirkpatrick & Cuban (1998), concluded from their research in which they reviewed access, use, attitude and students' achievement with computers in education, that when male and female students at all levels of education had the same amount and types of experience on computers, the females' achievement scores were similar to that of their male counter parts and that there was no significant difference between their achievement scores.

Imhanlahimi & Imhanlahimi (2008), also suggested the ineffectiveness of Computer Assisted Instruction alone not to be very effective for instruction without the presence of the teacher.

Gender has been one of the variables that has been studied in association to students' achievement with respect to computer simulations. However, it does not appear to be an important factor. Yusuf & Afolabi (2010), Spencer (2004), Huppert *et al.* (2002), Barnea & Dori (1999), Bello (1990) and Choi & Gennaro (1987) studied the influence of gender on working with computer simulations on students' achievement. Gender had no influence on students' performance in biology when taught with computer simulations in both individualized and cooperative settings (Yusuf & Afolabi, 2010). In a study by Choi &

Gennaro (1987), to investigate the effect of computer simulated experiments on Junior High School students' understanding of the volume displacement concept, they noted that there was no significant difference in performance between males and females using the computer simulations in the learning of the volume displacement concept. Choi & Gennaro (1987) posited that when gender gaps in achievement exist, they persist during the use of the computer simulations since the males are more used to computer applications than their female counterparts.

It therefore can be deduced from the review that the use of computer simulation instruction packages enhanced the performance of both male and female students without any statistically significant difference between them.

2.6 Computer Simulations in Chemistry

According to Srisawasdi & Panjaburee (2015), computers have become increasingly important among science educators, and play important roles during the instruction of students in the classroom and science laboratory.

Modelling and simulation are used in research and education to describe, explain and explore phenomena, processes and abstract ideas (Barnea & Dori, 2000). Rutten *et al.*, (2012) indicated its usefulness in concept learning and for visualization, because of the complex and invisible nature of some science concepts. However, these gains are realized by presenting dynamic theoretical or simplified models of real-world components, phenomena, or processes, and encouraging students to observe, explore, recreate, and receive immediate feedback about real objects, phenomena, and processes (Srisawasdi & Kroothkeaw, 2014).

Cook (2006) and Wu & Shah (2004) reported on visual-aid learning with simulations that, the visualizations (from the computer simulations), facilitated the integration of cognitively new knowledge with existing knowledge, which are important components of learning from the constructivist perspective, and improved conceptual understanding of scientific phenomena.

Tversky, Julie & Mireille (2002) had suggested that simulations need to adhere to two principles to be effective teaching and learning tools. These include; Congruence and Apprehension Principle. Congruence Principle states that, the structure and content of the external representation should correspond to the desired structure and content of the internal representation". That is, the use simulation used must mimics the process it intends to show or demonstrate. Apprehension Principle also states that the structure and content of the external representation should be readily and accurately perceived and comprehended (Tversky, Julie & Mireille, 2002).

Podolefsky *et al*. (2010) also recommended that teachers should use simulations that provide structures for exploration, such as concrete connections to the real world, representations that are not available in the real world, analogies to help students make meaning of and connect across multiple representations and phenomena, and a high level of interactivity with real-time, dynamic feedback. Through this process, students discover principles, rules, and characteristics of scientific phenomena as reported by Kroothkaew &

Srisawasdi (2013), implying that they could change their conception when alternative scientific concepts exist. Therefore, computer simulations can be used to enhancement of the students' conceptual change based on principles of constructivist learning theory (Dega *et al*., 2013).

2.7 Chemical Bonding; a Problematic Concept Area

The traditional pedagogical approach for teaching chemical bonding is often overly simplistic and not aligned with the most up-to-date scientific models. As a result, high-school students around the world lack fundamental understanding of chemical bonding (Levy *et al.,* 2007). According to Teichert & Stacy (2002), the traditional approach of teaching bonding is problematic. More specifically, during the last two decades, researchers have found that students lack a deep conceptual understanding of the key concepts regarding chemical bonding and fail to integrate their mental models into a coherent conceptual framework (Taber, 2001; Bodner & Domin, 1998; Herron, 1996).

Bonding is a central concept in chemistry at the Senior High Schools, and therefore a thorough understanding of it is essential for understanding almost every other topic in chemistry such as carbon compounds, proteins, polymers, acids and bases, chemical energy, and thermodynamics (Hurst, 2002). Bonding is considered by teachers, students, and chemists to be a very complicated concept (Robinson, 2003; Taber, 2001). The concepts associated with chemical bonding and structure, such as covalent bonds, molecules, ions, giant lattices, and hydrogen bonds are abstract and in order to understand these concepts, students must be familiar with mathematical and physical concepts that are associated with the bonding concept such as orbitals, electronegativity, and polarity.

Students' misconceptions regarding this concept have been noted worldwide since students live and operate within the macroscopic world of matter and do not easily follow shifts between the macroscopic and sub-microscopic levels (Robinson, 2003; Harrison & Treagust, 2000; Gabel, 1996). Consequently, they tend to build themselves alternative conceptions and non-scientific mental models (Taber & Coll, 2002).

In a study by Levy *et al*. (2004), it was reported that students possess a variety of misconceptions regarding the chemical bonding concept. Levy *et al.* (2007) also suggested that students demonstrate a superficial understanding of chemical bonding not only because this concept has intrinsic complexities but also because of external misleading factors concerning the traditional approach used for teaching the bonding concept. The Chief Examiners Report for WASSCE May/June 2013, reported that majority of the candidates could not specify the type of bonds present in some substance and could not describe the units that make up those substances. The Report concluded that, students lacked understanding of bonding and structure lattice of molecules (WAEC, 2013). In view of that, the researcher recommends making a radical change in the traditional approach used for teaching this concept.

2.8 The Concept of Chemical Bonding

Chemistry is dealing with the nature of substances and their transformations, which are essentially, abstract (Justi & Gilbert, 2002). The nature of substances and the physical and chemical changes of substances are derived from the interactions between atoms or charged particles (Coll & Treagust, 2003). Therefore, chemical bonding is one of the most central topics taught in chemistry at upper secondary school level, and is essential for other topics in chemistry (Nahum *et al*., 2008).

Several researchers have defined chemical bonding. Lagowski, (1997a) defined it as 'forces that hold atoms together in stable geometrical configuration' (p.336). Silberberg, (2003), also defined it as 'forces that hold atoms of elements together in a compound' (p.59). Parker (1997) also posited that it is a 'strong attractive force that holds together atoms in molecules and crystalline salts'. Lewis & Hawley, (2007) also stated that it is 'an attractive force between atoms strong enough to permit the combined aggregate to function as a unit'.

Bonding occurs to lower the potential energy between positive and negative particles, where the particles could be oppositely charged ions or atomic nuclei and the electrons between them (Silberberg, 2003). According to Atkins (1994), intermolecular forces are the forces responsible for holding molecules together, and affect the structure of solids and properties of liquids and real gases. The main types of bonding are ionic bonding, metallic bonding and covalent bonding and have been discussed below.

2.8.1 Ionic Bonding

Transfer of electrons from a metal to a non-metal is central when ionic bonding is explained (Silberberg, 2003; Chang, 2005). Silberberg (2003), describes this transfer as a central idea and a solid is formed when the resulting ions attract each other strongly.

Parker (1997) describe ionic bonding as a type of bonding in which one or more electrons are transferred from on atom to another. Chang (2005), also define ionic bonding as the electrostatic force that holds ions together in ionic compound, but use reactions in terms of transfer of electron to introduce ionic bonding. In contrast, this transfer is not central when ionic bonding is defined (Lagowski, 1997b). Ionic bonding is therefore defined by Lagowski (1997b) as the result of electrostatic attraction between negatively and positively charged atoms or groups of atoms or ions. Lagowski (1997c), later on posited that the charged particles in ionic compounds are ions. It is not surprising that Lewis & Hawley (2007), defined ionic bonding as the result of electrostatic attraction between oppositely charged ions at one place.

Ion formation requires energy, but a large amount of energy is released when the gaseous ions form a solid, called the lattice energy, also described as the enthalpy change when the gaseous ions form a solid (Silberberg, 2003). The lattice energy is also described as the energy required to overcome the attractive forces in an ionic compound (Lagowski, 1997b). The lattice energy depends on ionic size and charge, and can be calculated from the Born - Haber cycle (Silberberg, 2003; Chang, 2005; Lagowski, 1997b). The importance of the lattice energy is pointed out by Chang (2005) and Lagowski (1997b) that the lattice energy determines the stability of the ionic compound.

2.8.2 Covalent Bonding

The covalent bonding model not based on quantum mechanics is described in terms of sharing of electron pairs by two atoms, explained by the American Chemist G. N. Lewis in

1916, before quantum mechanics were established fully (Atkins, 1994). Covalent bonding was explained by Lewis as the sharing of electron pairs between two atomic centres, the electrons placed between them, with electrostatic force between the negative shared electrons and the positive nuclei (Lagowski, 1997b).

Each electron in a shared pair is attracted to the nuclei of both atoms and this attraction is responsible for covalent bonds (Chang, 2005). The molecule became stable if the atoms in the molecule then had a complete octet of electrons, and the shared electron pair is described as 'the glue that bonds the atoms together by electrostatic interaction' (Lagowski, 1997). According to Silberberg (2003), covalent bonds occur when a shared pair of valence electrons attracts the nuclei of two atoms and hold them together, filling each atoms' outer shell. This attraction draws the atoms closer, and repulsion between the atoms' nuclei and electrons occur. The covalent bond results from the balance between these attractions and repulsion, where the system has its minimum energy (Silberberg, 2003). Covalent bonding is also defined as a bond in which two electrons are shared by two atoms (Chang, 2005) or by two atomic nuclei or a pair of atoms (Lewis & Hawley, 2007), or as a bond where each atom of a bound pair contributes one electron to form a pair of electrons (Parker, 1997).

2.8.3 Polar Covalent Bonding

Polar covalent bonding is described in terms of covalent bonding with unequal sharing of electrons. This unequally sharing of electrons between the atoms emerges when atoms with different electronegativities form a bond (Silberberg, 2003) resulting in partially negative and positive poles of the bond (Silberberg, 2003), or that the electron density is shifted toward the more electronegative atom (Lagowski, 1997b, Lagowski, 1997c). The unequal sharing is also described to occur when one of the atoms holds the electron pair more closely (Parker, 1997) or the electrons lie nearer to one of the atoms in the bond, because of different attractive forces on the bonding electron pair (Hopp & Henning, 1983). Further reason for the unequal sharing is that the electrons spend more time in the nearby region of one atom than the other, seen as a partial electron transfer or shift in electron density where the property electro-negativity can be used to distinguish between non polar covalent bond and polar covalent bond (Chang, 2005).

Lewis (2007) does not use the term polar covalent bonds, instead covalent bonds are said to range from evenly shared electrons, nonpolar, to 'very unevenly shared', electrons, extremely polar. According to Atkins (1994), a covalent bond is non-polar when the electron sharing is equal and polar when it is unequal.

Valence Shell Electron Pair Repulsion (VSEPR) theory, is used to construct the molecular shape from Lewis' structure. Each group of valence electrons around a central atom is located as far away as possible from the others in order to minimize repulsion' (Silberberg, 2003). The three-dimensional arrangement of nuclei joined by the electron groups gives rise to the molecular shape.

A molecule with polar covalent bonds between the atoms and where the shape of the molecule leads to the molecule having a net imbalance of charge is called a polar molecule

(Silberberg, 2003). According to Chang (2005), a polar molecule is a molecule that has dipole moments, while Atkins (1994) defined polar molecule as a molecule with permanent electric dipole moment.

2.8.4 Metallic Bonding

Metallic bonding is explained in terms of the electron-sea model (Silberberg, 2003; Parker, 1997). In this model, the metallic lattice is described to consist of the atomic cores, seen as cations, surrounded by delocalized valence electrons that form an 'electron sea' (Silberberg, 2003), or immersed in a sea of delocalized electrons where the electrons attract the metal cations together (Chang, 2005; Silberberg, 2003). These valence electrons, free to move between the atomic cores, are also said to form a so-called electron gas, that 'glue' the cations of the metallic lattice together, that is, the metallic bonding (Hopp & Henning, 1983).

2.9 The Concept of Hybridisation

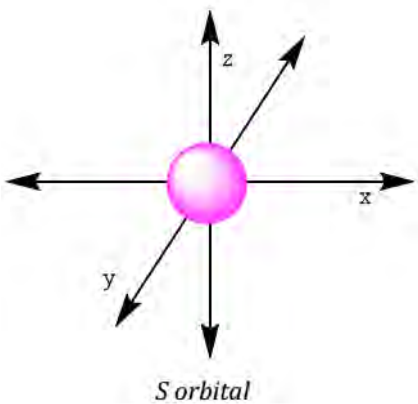
Fundamental questions of chemistry include how atoms are bonded together to form compounds and how the formulas and structures of the compounds are dictated by bonding forces (Nakiboglu, 2003). Molecular geometry and hybridization of these compounds play an important role in the teaching of students to improve reasonable imagination concerning the shapes of molecules and ions through the understanding of covalent bond theories. However, all bonding theories indicate that the hybridization or orbitals are just a model and should not be taken as a real phenomenon (Mohammed, 2009).

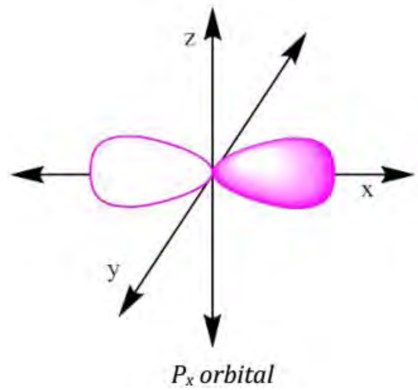
In the covalent bonding formation, the electrons involved in the bonding arise from the 'mixing' or 'overlapping' of orbitals to form new sets of similar orbitals that are different from the known (normal) orbitals like 's', 'p', 'd' and 'f' orbitals. The new atomic orbital becomes a 'hybrid' or a 'mixture' of the old orbitals and are intermediate between the old (mixing) orbitals involved. The process of orbital mixing is called hybridization, and the new orbitals are called hybrid orbitals.

Hybridization is therefore defined as the mixing up of different atomic orbitals of different energies of the same atom to form new orbitals with the same energy and shape (Sarpong, 2015). These hybrid orbitals result in the bond formation and as a result have lower energies than the highest energy level of the original orbitals. Sarpong (2015), posited that hybridization occurs only in covalent bonds and that it precedes covalent bond formation.

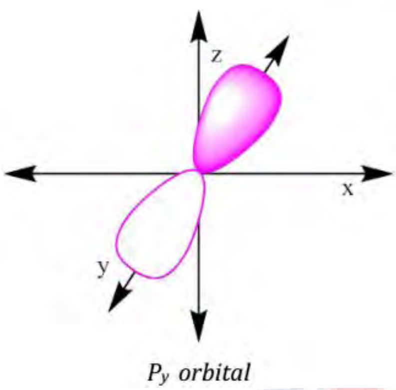
2.9.1 Atomic Orbitals

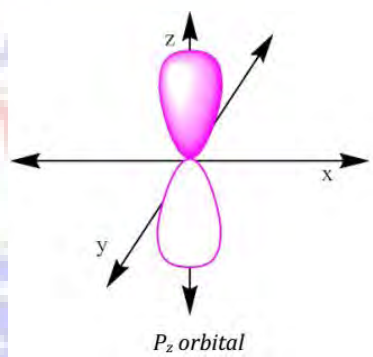
Orbitals are a model representation of the behaviour of electrons within molecules. In the case of simple hybridisation, the approximation is based on atomic orbitals, similar to those obtained for the hydrogen atom, the only neutral atom for which the Schrödinger equation can be solved exactly. Atomic orbital is therefore an expected region of electron density around an atom based on a solution to the Schrödinger wave function (Vollhardt, 2007).





S orbital Px orbital





Py orbital Pz orbital

Figure 1: The ‘s’ and ‘p’ orbitals

2.9.2 Types of hybridization

The various orbitals (s, p, d and f) can mix to give rise to different hybrid orbitals. Some authors (Schmid, 1996; Carey, 2003) have posited five (5) common types of hybrid orbitals or hybridization with various spatial (stereo) orientation or arrangement. They are sp, sp^2, sp^3, sp^3d^2 and sp^3d. The SHS syllabus (MoE, 2010), however, limits teachers to discuss only the first four (sp, sp^2, sp^3, sp^3d^2) even though the WAEC syllabus has no such restrictions and as such Sarpong (2015), described only the first four in his textbook.

2.9.2.1 sp hybridization

According to Vollhardt (2007), sp hybridization is the mixing up of two hybrid orbitals formed by the mixture of one 's' and one 'p' orbital. McMurry & Fay (1998) defined sp hybridization as the mixing up of one s-character and one orbital of p-character to form two hybrid orbitals of equivalent energy and shape. The sp hybrid orbital then is formed from the mixing of one s-orbital and one p-orbital to give two hybrid orbitals of equivalent energy and shape.

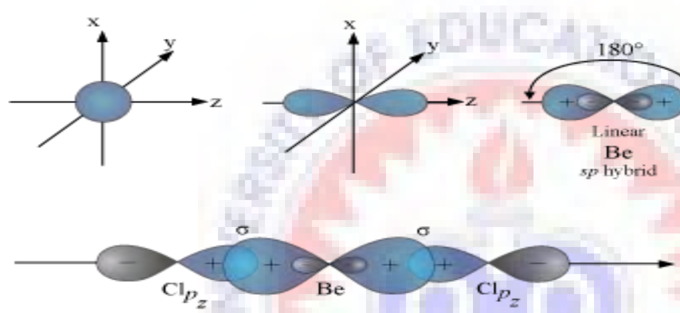


Figure 2: An sp hybridization showing the formation of $BeCl_2$

The shape of the hybrid orbital has one large and one small lobe, which differ markedly from those mixed. The angle between the sp orbital is 180° and thus the molecule formed by an sp-hybridised central atom will be a linear shape (Mohammed, 2009). Examples of molecules, which exhibit SP-hybridization, include $\underline{Be}H_2$, $\underline{Be}Cl_2$, $\underline{Be}F_2$, $\underline{C}S_2$, $\underline{C}O_2$ and O_2.

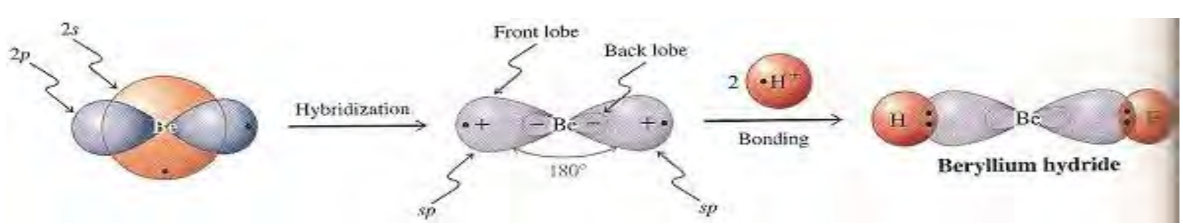


Figure 3: Formation of BeH_2 Source: Vollhardt, 2007

2.9.2.2 sp^2 hybridization

An sp^2 hybridization is a process in which one 's' and two 'p' orbitals combine to form three similar sp^2 orbitals. Thus, an sp^2 orbital is formed from mixing of one s and two p orbitals to give three sp^2 hybrid orbitals of equivalent energy and shape. Each of the three sp^2 hybrid orbital have 33% s character and 67% p character each. The last p orbital stays the same. The front lobes (and their corresponding back lobes) face in opposite directions (at 120° from each other). Electron repulsion therefore creates a trigonal planar geometry. The small amount of energy needed to promote an electron from the 2s to one of the 2p levels is compensated by bond formation (Sarpong, 2015).

2.9.2.3 sp^3 hybridization

sp^3 hybridization is the process where one 's' orbital and three 'p' orbitals 'mix' to form four similar hybrid orbitals or equivalent energy and shape and its directed towards the regular tetrahedron (Sarpong, 2015).

Figure 4: sp^3 Hybridization of CH_4

2.10 Organization of other chapters

The other chapters have been organized as follows; Chapter Three, presents the detailed research methodology. This chapter includes information on the research design, sampling techniques, research instruments, data collection procedure and data analysis. Chapter Four presents results of the study as guided by the research questions. The results have been tabulated and where necessary represented pictorially to make it more meaningful. Chapter Five is devoted to the summary of the study and conclusions drawn from the study. It also includes recommendations and suggestions for further study.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Overview

This chapter includes the research design, the study population, sample and sampling techniques, the intervention, research instrument, reliability of instrument, validation of instrument, data collection procedure and data analysis procedure that were used for this work.

3.1 Research Design

The study employed the quasi-experimental research design. This is because quasi-experiments are exceptionally useful in instances, such as, evaluating the impact of public policy changes, educational interventions or large scale health interventions (Shadish *et al.,* 2002). Quasi-experimental research design involves selecting groups, upon which a variable is tested, without any random pre-selection processes (Shuttleworth, 2008).

According to Gribbons & Herman (1997), the frequently used types of quasi-experimental research designs include the following: post-test only non-equivalent control group design, time series designs and pre-test-post-test non-equivalent control group design. Post-test only non-equivalent control group design involves administering an outcome measure to two groups or treatment groups after which a comparison is made (Gribbons & Herman, 1997).

This study employed post-test only non-equivalent control group design of the quasi-experimental research design. Quasi-experimental research approach was used for this study because the study used intact classes which did not permit random selection and assignment of participants. Post-test only non-equivalent control group design of quasi-experimental design was also used because the study investigated the effect of two teaching approaches: computer simulations teaching approach and the traditional teaching approach, on experimental and control groups, which has not been equated by randomization (Cohen, Manion & Morrison, 2008) in six SHSs in the Ashanti Region of Ghana.

The sequence in which the research was conducted have been summarized in a flowchart below;

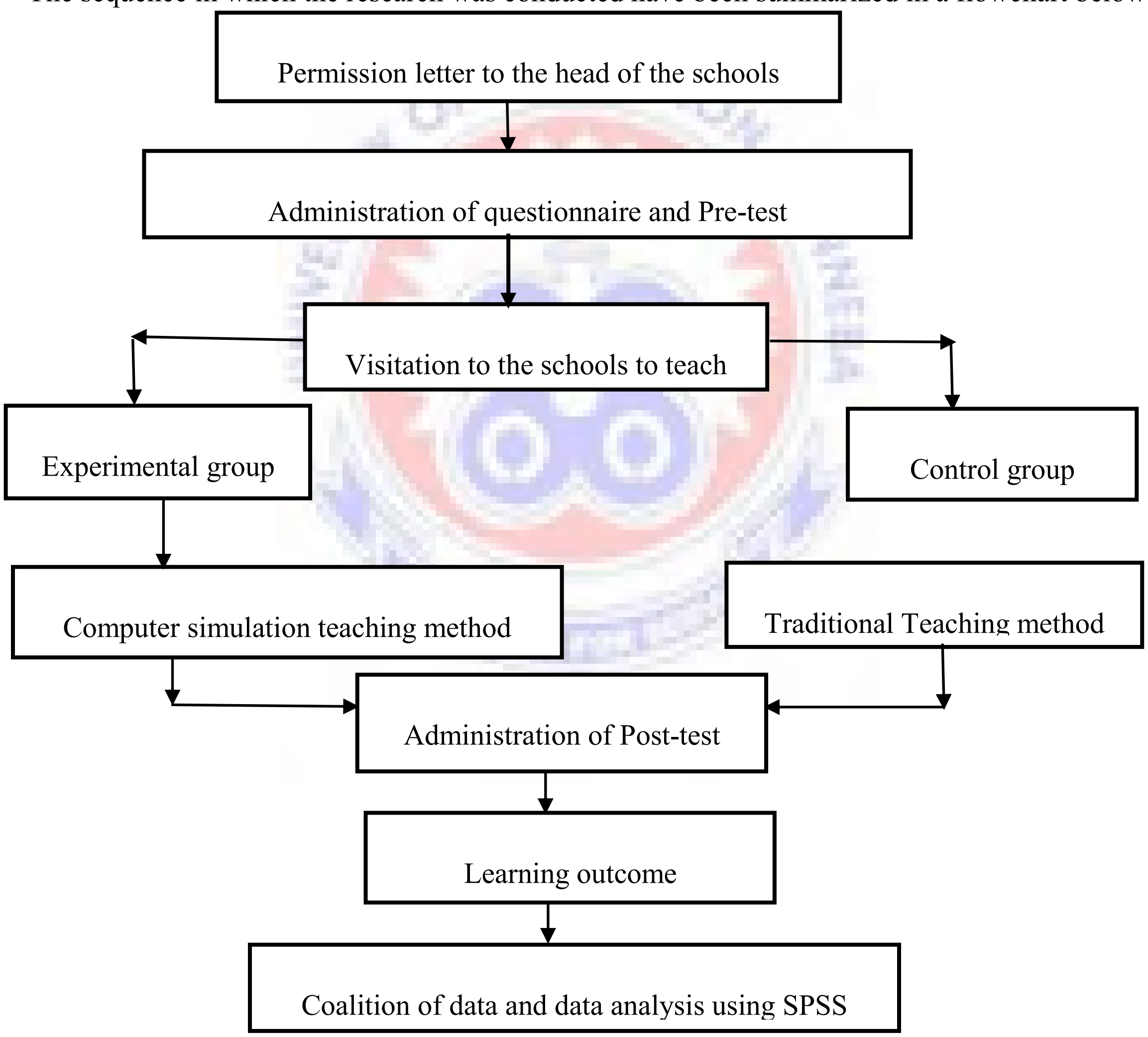


Figure 5: A flowchart showing the sequence in which the research was conducted

3.2 Population

The study targeted General Science Students in the Senior High Schools in the Ashanti region of Ghana. Six schools were selected purposively due to their proximity to the researcher. They were Anglican Senior High School (A), T. I. Ahmadiyya Senior High School (B), Osei Tutu Senior High School (C), Kumasi High School (D), Armed Forces Senior High School (E) and St Louis Senior High School (F). The population of the science students in the selected schools A, B, C, D, E and F were 319, 214, 170, 195, 130 and157 respectively, making a total of 1,185 students.

3.3 Sample and Sampling Techniques

The sampling technique used for the study was purposive sampling. The target sample in the study consisted of one hundred and eighty (180) second-year Senior High School Science students of 2015/2016 academic year from six (6) selected schools. The Experimental and the Control Groups for each selected school were made up of twenty-five (25) students and five (5) respectively. The choice of second year students was based on the fact that they had been taught chemical bonding.

3.4 Research Instruments

Three different instruments were used in this study to collect data. They were the researcher-created Students' Knowledge of Chemical Bonding Test (SKCBT), Pre-test Students questionnaire and Chemical Bonding Achievement Test (CBAT). The SKCBT and the CBAT were used to determine the Students' academic achievements in chemical bonding.

3.4.1 Students' Knowledge of Chemical Bonding Test (SKCBT)

The SKCBT consisted of fifteen (15) multiple-choice items and seven (7) compulsory essay type questions. The questions of the SKCBT were set to cover the different levels of instructional objectives and the content of the topics selected. The SKCBT is shown in Appendix A.

3.4.2 Chemical Bonding Achievement Test (CBAT)

The CBAT consisted of ten (10) compulsory essay type questions which test the understanding of students in the selected topics and their ability to apply the knowledge gained in the stimulation lessons to solving questions. The questions of the CBAT were set to cover the different levels of instructional objectives and the content of the topics selected. The CBAT is shown in Appendix B.

3.4.3 Pre-test Student Questionnaire

The Pre-test Student Questionnaire was used to collect data from the students before the intervention. The questionnaire was adapted from the studies conducted by Goodrum & Hackling (2003) and was modified to suit the purpose of this study. The questionnaire was divided into two sections. Section A, was constructed to elicit information about the name of the school, the students' class and sex. Section B contained questions about the students' interest in the study of chemistry, their punctuality in class, teaching methods employed by their teachers, frequency of practical activity in their schools, incorporation of Computer Simulation Instructional Packages in their classes, their access and familiarity with computers and their applications. The questionnaire is shown in Appendix C.

3.5 Reliability of Instruments

In order to ensure that the research instruments produced scores that are stable and consistent and their test items are devoid of any ambiguities, Creswell (2008), recommends that as much as possible, the questionnaire should be pilot-tested. The questionnaire was pilot-tested using fifteen (15) general science students from Jachie-Pramso Senior High School and fifteen (15) general science students from Prempeh College in the Ashanti Region of Ghana making thirty (30) students. Data from the pilot test were statistically analysed to determine the reliability of the test instruments. The analysis yielded Cronbach's Alpha Value Based on Standardized items as 0.67 (Appendix D) for the Pre-Test Student Questionnaire. According to Ary, Lucy & Asghar (2002), if the measurement results are to be used for making a decision about a group or for research purposes, then scores with modest reliability coefficient should not below 0.50. The above reliability coefficient for the questionnaire therefore, signifies that the test instrument is considerably reliable.

3.6 Validation of Instruments

According to Punch (1998), an instrument is considered valid when there is confidence that it measures what it is intended to measure in a given situation. A major portion of the SKCBT and the CBAT were extracted and modified from the West African Examinations Council past questions (from 1993 to 2015). This was to ensure that their appropriateness measures to the West African academic content standards in chemistry. The test items were prepared on the basis of the selected topics for the study and were submitted to some experienced chemistry teachers in two Senior High Schools, a WAEC Chemistry Examiner and my supervisor for scrutiny. The necessary corrections were effected accordingly in order to have the test item adequately certified. The research instruments used for the data collection were given to experienced chemistry teachers in Anglican Senior High School and St Louis Senior School, and one WAEC Chemistry Examiner, and a Science Educationist and finally to my supervisor for scrutiny in order to ensure the validity of the questioner.

3.7 Intervention

The participants in the Experimental Group were taught Chemical Bonding as prescribed in Section 3 Units 1, 2, and 3 of the Elective Chemistry syllabus using the computer simulations instructional methods. The participants in the Control Group were however, taught the same Section and Units of the SHS Elective Chemistry syllabus using the traditional instructional methods. The computer simulation instructional packages used in this study were adopted from online resources. The addresses of the resources have been provided below;

- ✓ http://www.middleschoolchemistry.com/multimedia/s,
- ✓ http://www.middleschoolchemistry.com/multimedia/chapter4/lesson4,
- ✓ http://bcs.whfreeman.com/webpub/Ektron/pol1e/Animated%20Tutorials/at0201/at_0201_chemical_bond.html,
- ✓ http://fikus.omska.cz/~bojkovsm/termodynamika/Obrazky/bindingstyper.swf,
- ✓ http://staff.aub.edu.lb/~hyaghi/LessonSamples/Atom/pages/explanations/cmpds.htm).

The Post-test instrument, Chemical Bonding Achievement Test (CBAT) (Appendix B), was administered to all participants after experimental groups had been treated with the intervention and the control group was treated with the traditional instructional approach. This was done to assess the effectiveness of the incorporation of the computer simulations instructional package in the teaching and learning of chemical bonding on the performance of the SHS 2 students used in the study. Data collected were collated and analysed. Figure 5 is a flow chart showing the sequence in which the research was conducted.

3.8 Data Collection Procedure

The Pre-test Student Questionnaire was administered to the 180 students selected from 6 schools (the total sample) to solicit for some information about them and the teaching and learning of chemical bonding in their school. The researcher educated the students on the whole exercise by explaining the various steps of the research to them. The Pre-Test Students Questionnaire was administered to students to complete them. The questionnaire was answered individually and collected back the same day. The questionnaire was collected after completion by students and was checked and verified by reading through to see if all items were answered. After all the questionnaires had been retrieved, the SKCBT was also administered to the students. The questionnaire and the test lasted 25 and 45minutes respectively. The researcher and the chemistry tutors supervised the test. The Post-test (CBAT) in the form of class test was conducted at the end of the four-week intervention period (March-April) which the researcher and chemistry teachers supervised. There was 100% retrieval from the respondents in all cases. Students' scores obtained from the SKCBT and CBAT were also recorded and analysed.

3.9 Data Analysis Procedure

Means, standard deviation, percentages, and the student t-test were calculated. Data obtained from both pre-test (SKCBT) and post-test (CBAT) were analysed using t-test to determine whether there was any significant difference in the SKCBT and the CBAT among the two groups. The independent samples t-test was also used to determine any significant mean differences in academic achievement between the control and experimental groups. SPSS (version 20) and Microsoft excel were used for all the data analysis. The null hypothesis was tested at 0.05 level of significance. Results were tabulated and also presented pictorially for easy understanding as bar graphs and pie charts. These are presented in Chapter four of this report.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This chapter presents the results of the study guided by the research questions. The purpose of this study was to investigate the influence of Computer Simulation Instructional packages on Ghanaian SHS Students' performance in Chemical Bonding.

The results have been tabulated and where necessary represented pictorially to make it more meaningful. Presentation of the entire results is followed by the discussion of the findings.

4.1 Results

Beginning with research question one, the results are presented as follows.

4.1.1 Research Question 1: What is the initial performance of students before the intervention?

This question was posed to determine initial performance of the students prior to the intervention. In order to find out the performance of students in chemical bonding before the intervention, a Pre-test, labelled as Students Knowledge in Chemical Bonding Test (SKCBT) was administered to both control and experimental group. The total score was 30 marks. The performance of the students in the Pre-test (SKCBT) is shown in Table 1 for the Control Group.

From Table 1, the minimum score obtained by students in the Control Group was 15 marks whiles the maximum was 22 marks.

Table 1: Performance of Control Group in Pre-test

Marks (30)	Frequency	Percent
15	2	6.7
16	5	16.7
17	6	20.0
18	3	10.0
19	7	23.3
20	2	6.7
21	4	13.3
22	1	3.3

Two students had the minimum score whiles only 1 student had the maximum score. The highest frequency was 7 students scoring a mark of 19. The performance of Experimental group in the Pre-test is presented in Table 2.

Table 2: Performance of Experimental Group in Pre-test

Marks (30)	Frequency	Percent
12.0	1	0.67
13.0	1	0.67
14.0	7	4.67
15.0	11	7.33
16.0	24	16.00
17.0	23	15.33
18.0	13	8.67
19.0	21	14.00
20.0	19	12.67
21.0	8	5.33
22.0	15	10.00
23.0	4	2.67
24.0	1	0.67
25.0	2	1.33

The Pre-test results of the Experimental Group shown in Table 2, indicates the minimum score to be 12 and the maximum score to be 25. The minimum score was recorded by only one student whiles the maximum mark was scored by 2 students. The marks of the Control and the Experimental group seem to differ to a certain extent.

4.1.2 Testing of Hypothesis with Respect to Research Question One

To determine whether the difference in the initial performance of students before the intervention were statistically significant, research question 1 was formulated into a null hypothesis and tested.

It was hypothesized that:

Ho 1: There is no statistically significant difference between the initial performance of students in chemical bonding before the intervention.

Independent samples *t*-Test analysis for the Pre-test showed that the difference in performance between Experimental Group and the Control Group was not statistically significant, $t\ (178) = 0.198$, $p = 0.84$ as shown in Table 3.

This showed that there was no significant difference in performance between the control group and the experimental group prior to the intervention, although their scores seem to differ on the 'face-look'.

Table 3: Independent Sample Test of the Pre-test of the Control and Experimental Groups

CATEGORY		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
PRE-TEST	**Equal variances assumed**	4.003	0.047	**0.198**	**178**	**0.84**	0.100	0.505	-0.896	1.096
	Equal variances not assumed			0.241	52.429	0.81	0.100	0.415	-0.733	0.933

In the light of this analysis therefore, the first null hypothesis (*Ho 1*) was thus accepted that, 'There is no statistically significant difference between the initial performance of students (both control and experimental group) before the intervention'. It can therefore be posited that the Experimental Groups was no better in performance than the Control Group. Hence, a change in performance of the Experimental Group could be attributed to the treatment given them. Furthermore, it is observed from the Pre-test scores that all students scored at least half of the total marks, suggesting students have a fair understanding of the subject matter. It was not surprising that 179 (99.4%) students intimated on the Pre-test Students Questionnaire that they have been taught chemical bonding (Figure 6).

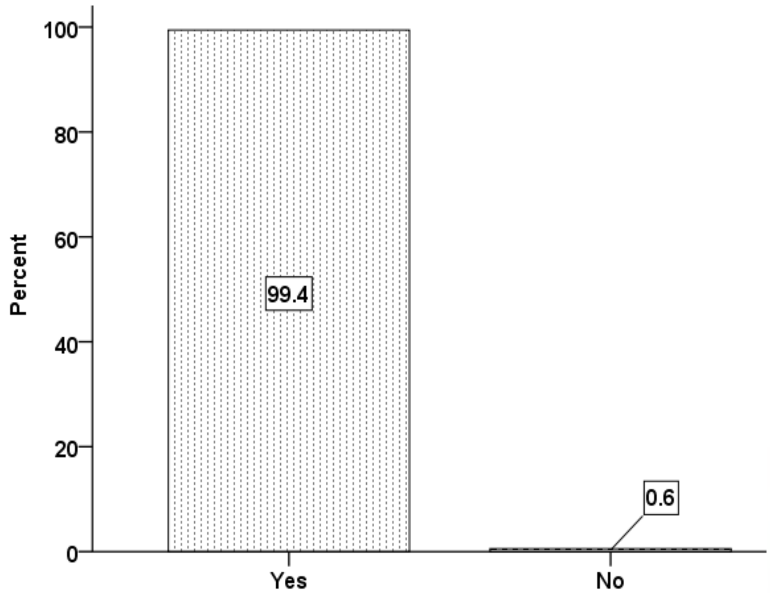


Figure 6: A bar chart showing students' responses to the question 'Have you been taught Chemical Bonding?'

4.1.3 Research Question 2: To what extent will the intervention influence the performance of the students in chemical bonding?

This question was posed to determine whether the performance of students' after the intervention had significantly improved. In order to find out the performance of students in chemical bonding after the intervention, a Post-test, labelled as Chemical Bonding Achievement Test (CBAT) (Appendix B) was administered to both Control and Experimental Group. The total score of the CBAT was 30 marks. The distribution of scores on the Post-test for the Control group is presented in Table 4.

Table 4: Distribution of Score on Test After Training (Post-test) of Control Group

Marks (30)	Frequency	Percent	Cumulative Percent
16	1	3.3	3.3
17	1	3.3	6.7
18	5	16.7	23.3
19	7	23.3	46.7
20	3	10.0	56.7
21	7	23.3	80.0
22	3	10.0	90.0
23	1	3.3	93.3
24	2	6.7	100.0

From Table 4, the minimum score of the Control Group was 16 marks and the maximum score was 24 marks. One student had the minimum score whiles two students had the maximum score. The highest frequency was 7 students scoring a mark of 19 and 21 each.

The distribution of scores on the Post-test for the Experimental Group is presented in Table 5. From Table 5, the minimum score was 20 marks and was recorded by eight (8) students. Two students had the highest score of 30 marks. The results showed that the Experimental Group performed better in the Post-test as compared to their Pre-test results.

Table 5: Distribution of Score on Test After Training (Post-test) of Experimental Group

Marks (30)	Frequency	Percent	Cumulative Percent
20.0	8	5.3	5.3
21.0	14	9.3	14.7
22.0	12	8.0	22.7
23.0	26	17.3	40.0
24.0	24	16.0	56.0
25.0	24	16.0	72.0
26.0	16	10.7	82.7
27.0	9	6.0	88.7
28.0	10	6.7	95.3
29.0	5	3.3	98.7
30.0	2	1.3	100.0

This observation intimates that the Computer Simulation Instructional methods of teaching appear to have improved the performance of the students. There was a considerable increase in the mean score of the Experimental Group.

4.1.4 Testing of Hypothesis with Respect to Research Question Two

To determine whether the intervention would improve the performance of students (experimental group), research question 2 was formulated into a null hypothesis and tested.

It was hypothesized that:

Ho 2: There will be no significant improvement in the performance of the students in chemical bonding as a result of the intervention?

Independent sample *t*-Test analysis for the Post-test of the Experimental Group showed an improvement in performance between the Experimental Group and the Control Group after the intervention and their mean differences was found to be statistically significant, t (178) = 9.141, p = 1.39E-16 as shown in Table 6.

Table 6: Independent Sample Test of the Post-test of the Control and Experimental Groups

CATEGORY		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
POST-TEST	**Equal variances assumed**	1.415	0.236	**9.141**	**178**	**1.39E-16**	4.24	0.464	3.32	5.16
	Equal variances not assumed			10.389	47.74	7.63E-14	4.24	0.408	3.42	5.06

This showed that there was significant improvement in the performance of the Experimental Group than the Control Group after the intervention. It was therefore, concluded that the intervention improved significantly the performance of the students. In the light of this analysis, the second null hypothesis (*Ho 2*) was thus rejected for the alternate hypothesis that, 'There will be significant improvement in the performance of the students in chemical bonding as a result of the intervention.

Findings with respect to research question two was positive in that, the performance of the Experimental Group was significantly better than that of the Control Group on the CBAT.

Hence it can be posited that the computer simulation instructional methods of teaching improve students understanding better than the traditional method.

These findings are congruent with a current report by Srisawasdi & Panjaburee (2015), in which they observed students' conceptual understanding score to have increased resulting in a better progression of scientific understanding when students were exposed to computer-assisted instruction. The observed improvement is students' performance after they were exposed to the intervention reaffirm the findings of other researchers (Kara & Kahraman, 2008; Kara & Yesilyurt, 2007; Kiboss *et al*., 2006; Akour, 2006; Akpan & Andre, 2000).

These findings agree with that of Akour (2006) who reported that students taught using traditional instruction combined with the use of computer performed significantly better than students taught using the traditional instruction in a college setting. Again, Akpan & Andre (2000) examined the prior use of simulation of frog dissection in improving students' learning of frog anatomy and morphology. The study of Akpan & Andre (2000) indicated that students receiving simulation before dissection and simulation only learned significantly more anatomy than students receiving dissection only.

The findings are also congruent with those of Mwei, Too & Wando (2011) and Udousoro (2000) in mathematics; Bayrak (2008); Karamustafaoğlu, Aydın & Özmen (2005) and Kiboss & Ogunniyi (2003) in physics and Okoro & Etukudo (2001) in chemistry. These studies posited that computer simulations instructional approach was effective in enhancing students' performance than the traditional or conventional classroom instruction in subjects other than biology and chemistry and physics.

However, the findings of the study contradict that of Owusu, *et al*., (2009), Strauss & Kinzie (1994) and Duhrkopf & Kramer (1991). These studies indicated that students' achievements in biology were not improved significantly by means of the computer simulations instructions. Imhanlahimi & imhanlahimi (2008) also reported that Computer Assisted Instruction (CIA) alone was ineffectiveness of to be used for instruction without the presence of the teacher.

4.1.5 Research Question 3: By what margin will the intervention significantly improvement the performance of students?

This question was posed to determine the margin by which the intervention will significantly improve the performance of students? The Group Statistics of the Pre-test and Post-test for both Experimental and Control group is presented in Table 7.

Table 7: Group Statistics of the Pre-test and Post-test for both Experimental and Control Groups

CATEGORY		N	Mean	Std. Deviation	Std. Error Mean
PRE TEST	**Experimental Group**	150	18.267	2.6207	0.21
	Control Group	30	18.167	1.9491	0.36
POST TEST	**Experimental Group**	150	24.240	2.3819	0.19
	Control Group	30	20.000	1.9652	0.36

Table 2 and Table 5 show the scores of the Experimental Group for the Pre-test and the Post-test respectively. The minimum score of the Experimental Group in the Post Test had increased from 12 to 20 (representing a 26.67% increase) whereas the maximum score had also increased from 25 to 30 (representing a 16.67% increase). The Group Statistics of the Pre-test and Post-test for the Experimental and Control Group presented in Table 7, indicate an appreciable improvement in Experimental Groups' performance from a mean score of 18.27 (±2.62) to 24.24 (±2.38) in the Pre-test and the Post-test respectively. However, marginal improvement is seen in the Control Groups' performance from a mean score of 18.17 (±1.95) to 20.00 (±1.97) in the Pre-test and the Post-test respectively. The percentage improvement observed in the Control Group was 6.1% (Appendix E) and that of the Experimental Group was 19.9%. The degree of significant improvement for the Experimental Group was therefore determined to be 13.8% (Appendix E). This shows that there was significant improvement in the performance of the Experimental Group after the intervention.

4.1.6 Research Question 4: Will there be statistically significant difference between performance of male and female students in the experimental group?

This question was posed to determine if the performance of male students would be significantly different from that of female students when exposed to the intervention. The paired group statistics of the Pre-Test and Post-Test of Male and Female students are summarized in Table 8.

Table 8 shows that the males were 117 (making up to 65% of the research subjects) and the females were more 63 (making up to 35% of the research subjects).

Table 8: Group statistics of Pre Test and Post Test for Male and Female Students

	Sex	N	Mean	Std. Deviation	Std. Error Mean
PRE-TEST	Male	117.0	18.10	2.63	0.24
	Female	63.0	18.52	2.29	0.29
POST-TEST	Male	117.0	23.32	2.68	0.25
	Female	63.0	23.94	3.00	0.38

The mean score of the males in the Pre-Test was 18.10±2.63 and that of the female students were 18.52±2.29. The mean score of the male students in the Post-Test was 23.32±2.68 and that of the female students was 23.95±3.00.

4.1.7 Testing of Hypothesis with Respect to Research Question Four

To determine if there is a statistically significant difference in the performance of male students and that of female students, research question 4 was formulated into a null hypothesis and tested. It was hypothesized that:

Ho 3: There is no statistically significant difference between the performance of male and female students in chemical bonding when exposed to the intervention.

Independent sample samples Test analysis for the Pre-Test and Post-Test, for Male and Female Students showed that there was no significant difference in the performance of male and female students exposed to the intervention and their mean differences were found not to be statistically significant, for Pre-Test: t (178) = -1.07, p = 0.285 and for Post-Test: t (178) = -1.42, p = 0.157 (Table 9).

Table 9: Independent samples test of Experimental Group Pre-Test and Post-Test for Male and Female Students

CATEGORY		**Levene's Test for Equality of Variances**		**t-test for Equality of Means**						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
PRE-TEST	Equal variances assumed	0.77	0.381	**-1.07**	**178.0**	**0.285**	-0.42	0.39	-1.20	0.35
	Equal variances not assumed			-1.12	142.6	0.266	-0.42	0.38	-1.17	0.32
POST-TEST	Equal variances assumed	1.76	0.187	**-1.42**	**178.0**	**0.157**	-0.62	0.44	-1.48	0.24
	Equal variances not assumed			-1.37	115.1	0.173	-0.62	0.45	-1.52	0.28

This shows that there is no significant difference in the performance of male students and female students in chemical bonding when exposed to the intervention. It was therefore, concluded that the performance of male students was the same as that of the female students. In the light of this analysis, the third null hypothesis (*Ho 3*) was thus accepted that 'There is no statistically significant difference between the performance of male and female students in chemical bonding when exposed to the intervention'.

It is therefore suggested from Table 9 that, there was no gender disparity in the performance of the students exposed to the Computer Simulation Instructional methods in the teaching and learning of chemical bonding.

These findings are congruent with the findings of several researchers (Yusuf & Afolabi, 2010; Spencer, 2004; Kirkpatrick & Cuban, 1998; Bello, 1990; Choi & Gennaro, 1987), in which it was posited that academic performance of science students were not influenced by their gender. Choi & Gennaro (1987) posited that there was no significant difference in performance between males and females using the computer simulations in the learning and further intimated that when gender gaps in achievement exist, they persist during the use of the computer simulations since the males are more used to computer applications than their female counterparts are.

However, the findings of the study contradict reports of some other researchers (Danmole, 1998; Novak & Mosunda, 1991; Okeke & Ochuba, 1986), in which they asseverated that male students performed better than their female counterparts in biology, chemistry and physics.

Another twist to these findings is the report of Kelly (1978) and Wonzencreaft (1963), in which they posited that female were better academically than their male counterparts when they were taught with computer simulation instructional packages in science.

It therefore can be deduced from the review that the use of computer simulations instruction packages enhanced the performance of both male and female students without any statistically significant difference between them. Hence, the effect of computer simulations instructions on students' performance seems to be mixed. However, based on the strength of the findings of this study, a strong case can be made in favour of incorporating computer simulations instructional packages in biology teaching and learning at the SHS level in Ghana.

4.2 Findings and Analysis of Students' Responses to Pre-Test Students Questionnaire

The Pre-test students' questionnaire was used to solicit information form the students with respect to the teaching and learning of chemical bonding in their schools. Data from the questionnaire is presented and further discussed below.

The percentage of students who are interest in studying chemical bonding is presented pictorially with a bar graph in Fig 7. From Fig 7, 91.7% representing 165 students indicated that they have interest in studying chemical bonding where as 8.3% representing 15 students indicated that they are not interested in studying chemistry.

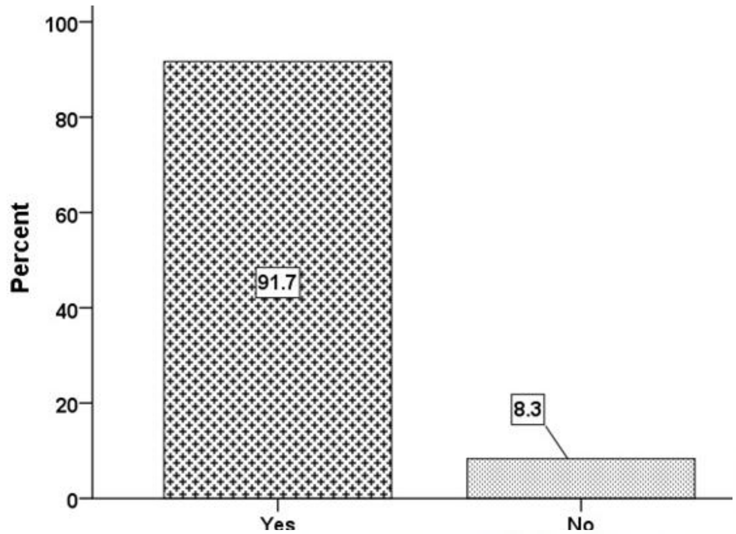


Figure 7: Percentage of students who have interest in studying Chemistry

A Non-Parametric Binomial Test confirmed a greater percentage of students to have interest in studying chemical bonding as the p-value (3.70E-33) is less than 0.05. as shown in Table 10. It was therefore, concluded that a greater percentage of the students have interest in studying chemical bonding.

Table 10: A Non-Parametric Binomial Test of percentage of students interested in studying chemical bonding

Question		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Do you have an interest in studying Chemistry?	**Group 1**	Yes	165	0.92	0.50	3.70E-33
	Group 2	No	15	0.08		
	Total		180	1.00		

Majority of the students (60%) who indicated that they don't have interest in studying chemical bonding suggested that chemical bonding looked very abstract (Table 11).

Table 11: Reasons student gave for not having interest in studying chemical bonding

Why you don't have interest in studying chemical bonding	
Responses	**Frequency (%)**
Chemical bonding look very abstract to me	9 (60%)
The concept of chemical bonding is very difficult to understand	2 (13.3)
I easily forget after being taught	4 (26.7%)

On the other hand, majority of the students indicated that they have interest in the study of chemical bonding (Table 12).

Table 12: Reasons student gave for having interest in studying chemical bonding

Why do you have interest in studying chemical bonding?	
Responses	**Frequency (%)**
Chemical bonding is an interesting concept	54 (32.7 %)
I enjoyed how my teacher taught me the concept of chemical bonding	42 (25.5%)
Chemical bonding was an intriguing concept as it satisfied my curiosity to understand how some compounds have different shapes, energies and bond angles	69 (41.8%)

Reasons stated by students included, chemical bonding is an intriguing concept as it satisfied their curiosity to understand how some compounds have different shapes and different bond angles.

Students were asked if they have had chemistry practical lessons over the period. Majority of the students' responded in the affirmative (Figure 8).

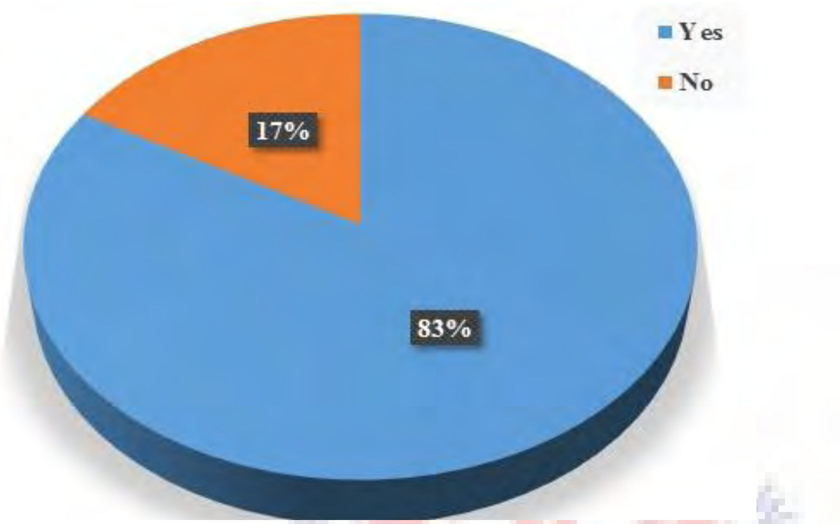


Figure 8: A pie chart showing students' responses to having practical lessons in chemistry.

It was found out that most students were introduced to practical lessons in SHS 1 (Figure 9).

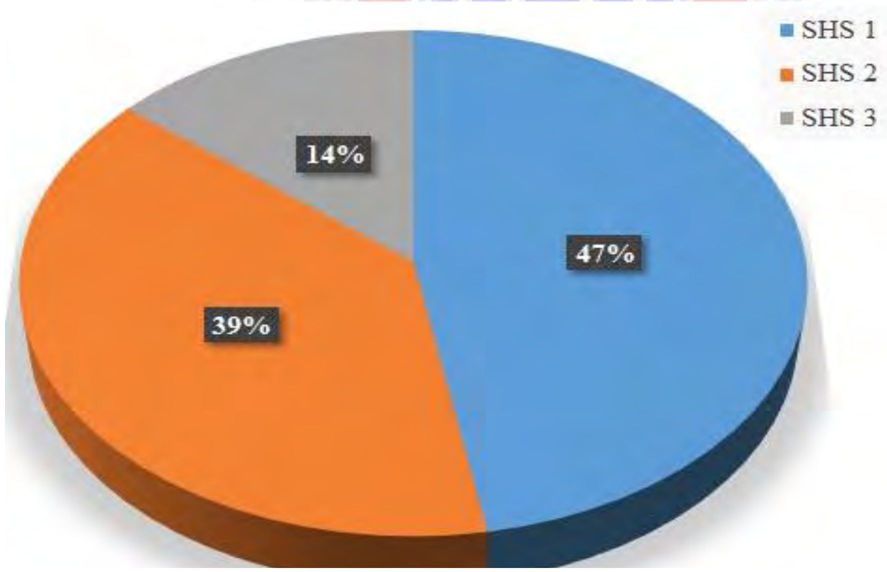


Figure 9: A pie chart showing level at which students are introduced to practical lessons in chemistry

However, the frequency of the practical lessons (Figure 10) was not encouraging probably, the practical lessons are not fixed on the students' timetable or if present, teachers might be using such periods for teaching theoretical aspects of the syllabus.

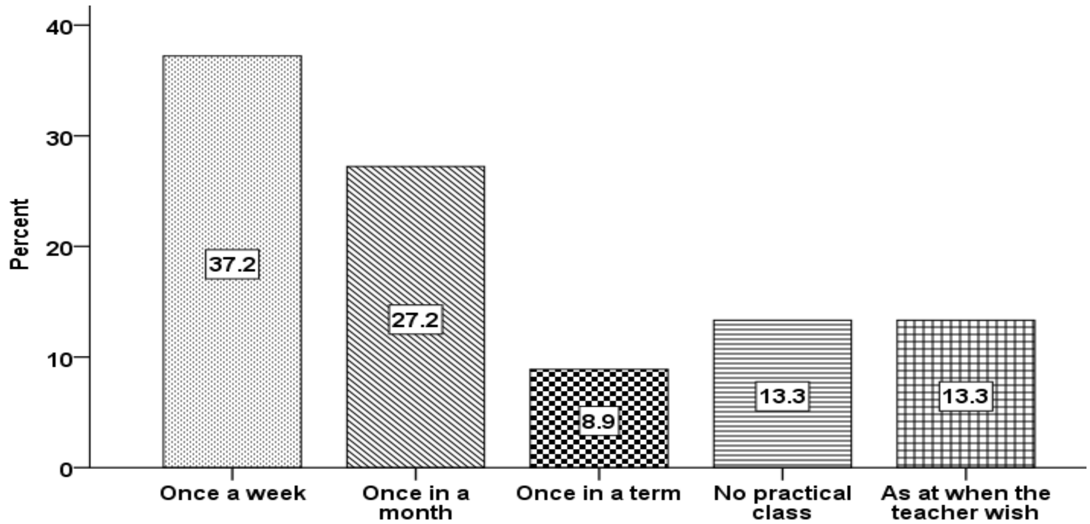


Figure 10: Frequency of chemistry practical lessons

From Figure 11, most students were taught with the practical and discussion method. These findings are inconsistent with the previous since practical lessons was not frequent.

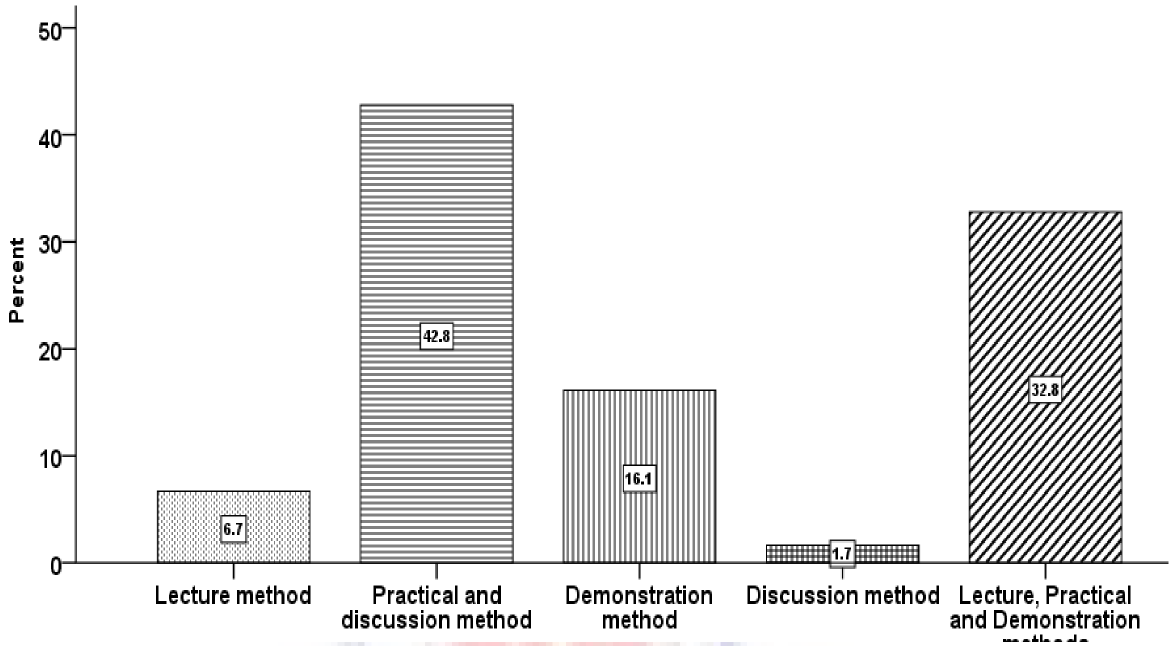


Figure 11: Students' responses to the type of teaching method their teacher uses in teaching chemical bonding

These inconsistencies might be due to the fact that students probably did not understand this particular question very well.

However, students indicated that they prefer the practical and discussion method (Figure 12) as the instructional medium.

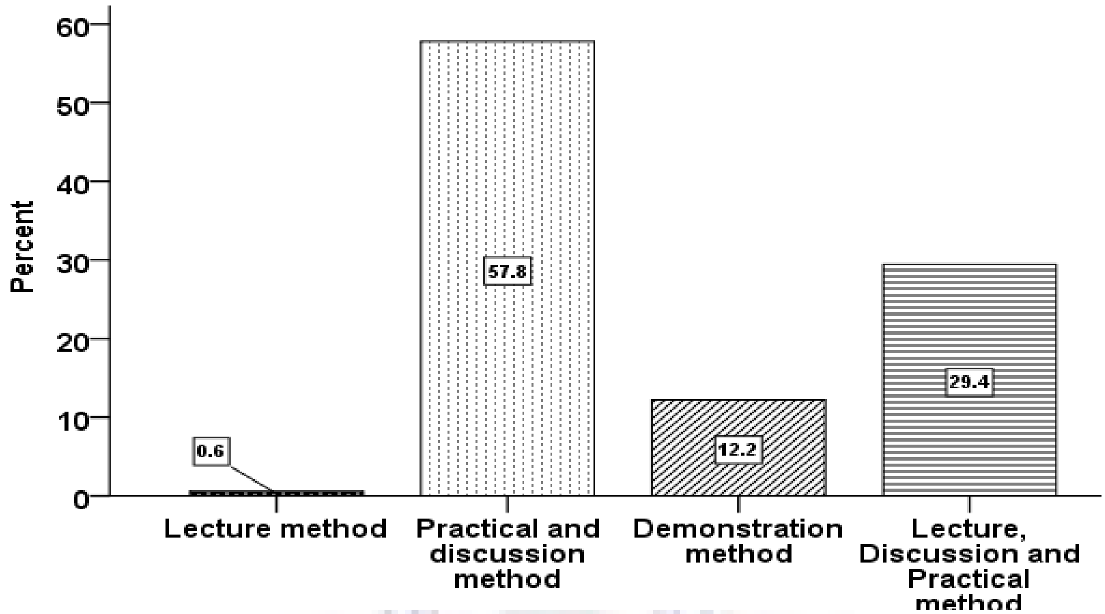


Figure 12: Students' preferred teaching methods for chemical bonding

From Figure 13, it is evident that most teachers do not integrate ICT in their instructional medium as well as Computer Simulation Instructional packages (Figure 14).

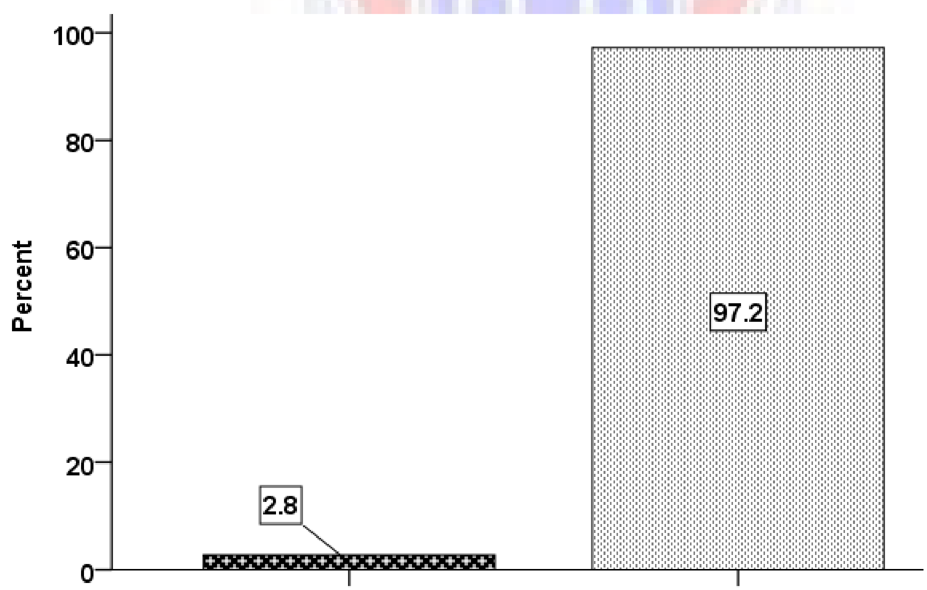


Figure 13: Students' responses to the integrating of ICT in the teaching of chemical bonding by their teachers

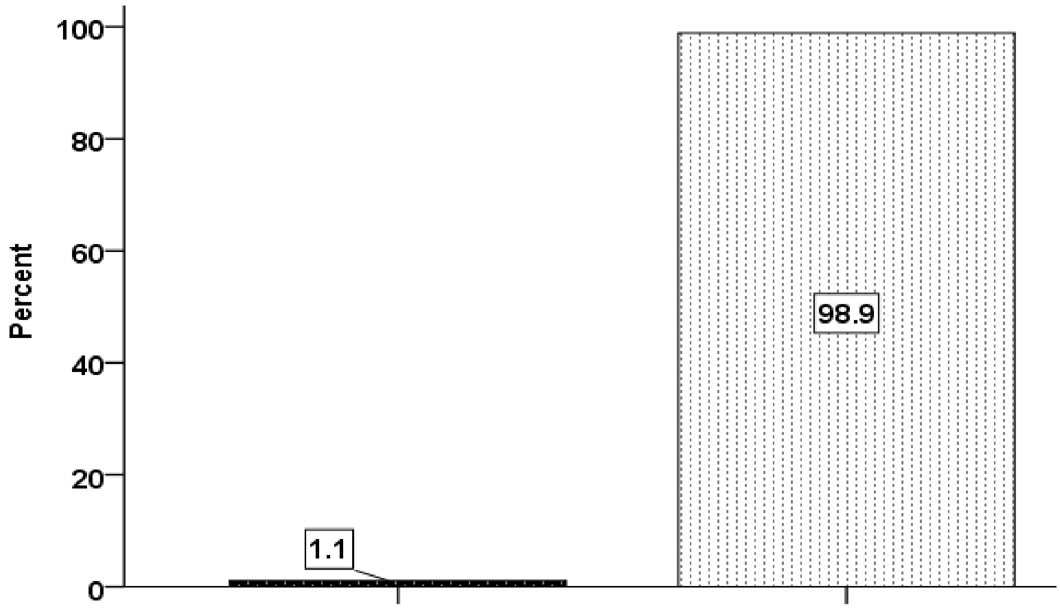


Figure 14: Students' responses to the use of Computer Simulation Instructional Packages in the teaching of chemical bonding by their teachers

That notwithstanding, a greater percentage of the students had skills in the use of computers (Figure 15). It was baffling to know that in this era where ICT classes have been incorporated into the curriculum at the SHS, there are still some students who do not have skills in the use of computers.

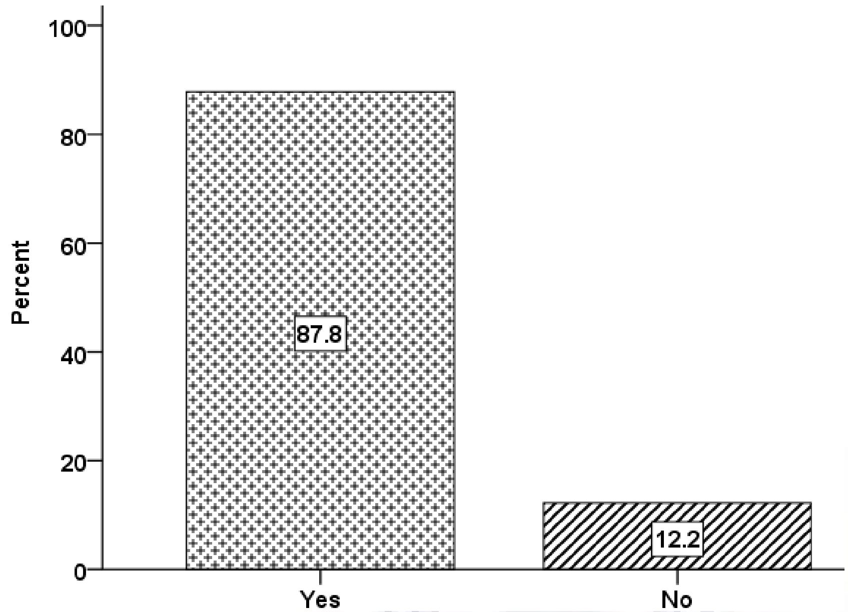


Figure 15: Proportion of students with or without skills in the use of computer

Most students had good reasons for studying chemistry in school (Figure 16) but there is the need that the career guidance units in the schools step up their activities to help direct the focus of the few students who might have missed the essence of studying chemistry.

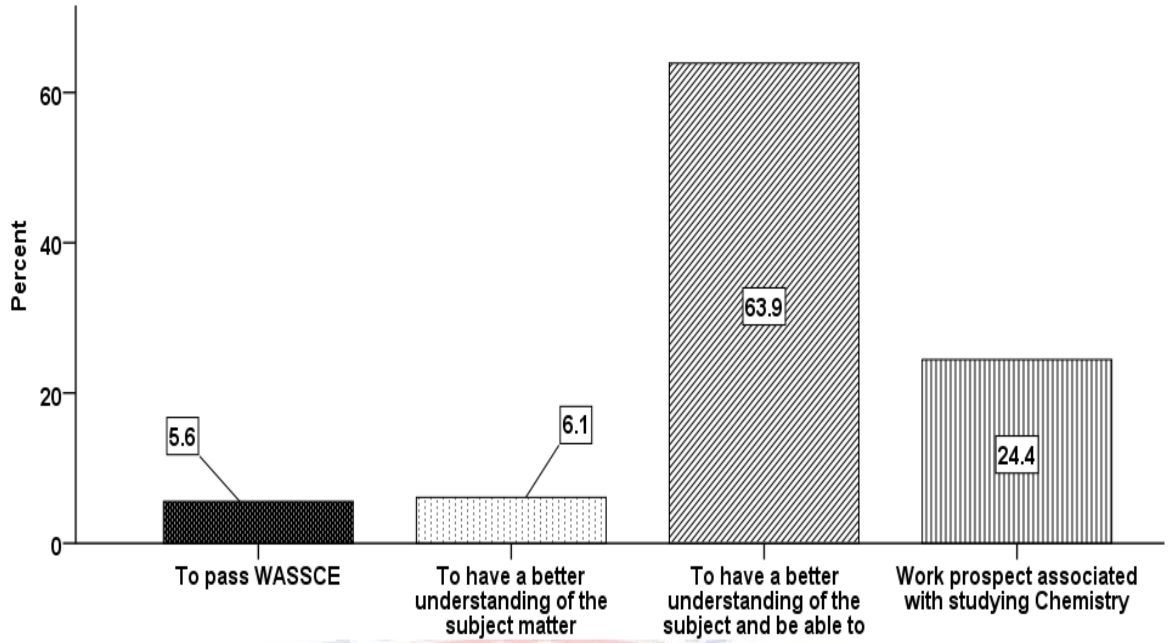


Figure 16: Students' main focus in studying chemistry

CHAPTER FIVE

SUMMARY, CONCLUSION, RECOMMENDATIONS AND SUGGESTIONS

5.0 Overview

This chapter is devoted to the summary of the study and conclusion drawn from the findings of the study. Additionally, the recommendations based on the findings of this study and suggestions for further studies have also been presented in this chapter.

5.1 Summary of the entire Study

The purpose of the study was to investigate the influence of Computer Simulation Instructional methods on Students' performance in Chemical Bonding using quasi-experimental research approach. The study was delimited to 180 second-year science students at the SHS level from six schools in Ashanti Region. The main instruments used were researcher-created Students' Knowledge of Chemical Bonding Test (SKCBT) and Chemical Bonding Achievement Test (CBAT), supported with Pre-test Students Questionnaire. The study revealed a significant ($p<0.05$) improvement in students' performance in chemical bonding after the intervention. Notwithstanding the general abstractness of chemical bonding, majority of students were found to have interest in the subject matter under study (chemical bonding).

5.2 Summary of Findings of the Study

This section focuses on the summary of the major findings of this study. It deals with the summary of the differences in performance between: the experimental and control groups, performance of students in the various schools and the gender disparity in the performance of students.

5.2.1 Initial Performance of Students Before the Intervention

The initial performance of the Experimental Group was the same as that of the Control Group on the Students' Knowledge in Chemical Bonding Test (SKCBT), signifying that the Experimental Group was no better in performance than the control group before the intervention as their mean difference was not statistically significant.

5.2.2 Improvement in Performance of Experimental Group in the Post Test

The mean score of Control Group increased from18.17 (±1.95) to 20.00 (±1.97), resulting in a 6.1% improvement whereas that of the Experimental Group also increased from 18.27 (±2.62) to 24.24 (±2.38) resulting in a 19.9% improvement. The degree of improvement in the performance was thus 69.3%. There was a significant difference in the performance of students exposed to the intervention. This indicates that the intervention appears to have a positive influence on students' understanding of the concept of chemical bonding.

5.2.3 Determination of Gender Disparity in Performance of the Post Test

The performance of male students was found not to be significantly different from that of female students after they were exposed to the intervention, signifying that the performance of male students was the same as that of the female students. This shows there was no gender disparity in the performance of the students.

5.2.4 Findings from Questionnaire administered to Students

The majority of students have interest in the studying of chemical bonding. Most students about 91.7% representing 165 out of the 180 intimated that they have interest in studying chemical bonding, signifying that students really have interest in studying chemical bonding. The few who said they do not have interest in studying chemical bonding suggested reasons such, chemical bonding looked very abstract, the concept is very difficult to understand and they easily forget after they are taught, as being the main cause of them not having interest in the concept. Almost all the students intimated that they have been taught chemical bonding and that their focus in studying chemistry was to have a better understanding of the subject matter and be able to apply its principle in life. Although chemistry practical lessons were found to be going on in the schools its frequency was found not to encouraging that notwithstanding, majority of the students were found to have been introduced to chemistry practical lessons in SHS 1. Concerning the methods of teaching, most students preferred the teaching methods their teachers used in teaching them chemical bonding suggesting that the students are satisfied with the instructional methods employed by their teachers. Concerning the incorporation of ICT into the instruction medium, it was found out that most of the teachers do not integrate ICT (simulations, audio, audio visuals, web based materials, etc) into the instruction medium in their schools although, a greater percentage of the students had skills in the use of the use of computers.

5.3 Conclusion

This study has revealed that students exposed to the computer simulations instructional methods in the teaching and learning of chemical bonding performed significantly better than their counterparts exposed to the traditional instructional approach did. The degree of significant improvement of the experimental group was 19.9%, which was a 13.8% more than that of the control group. There was no gender disparity in the performance of students exposed to the intervention. In the mist of the general abstractness of chemistry, majority of students have interest in the study of chemical bonding, which is as one of the abstract concepts in chemistry at the SHS level. Students focus in studying chemistry was positive. Chemistry practical lessons were not regular in the schools and students were satisfied with the instructional methods employed by their teachers, although, most teachers do not integrate ICT into the instructional medium in their schools, a greater percentage of the students had skills in the use of computers.

5.4 Recommendations

Based on the findings of this study, the following recommendations are made:

1. Innovative and more effective learner-centred instructional strategies, such as computer simulations instructional packages, should be used by chemistry teachers in the SHS to promote meaningful learning of difficult and abstract chemistry concepts like chemical bonding, organic chemistry among others.
2. The Curriculum Research and Development Division (CRDD) of the Ghana Education Service (GES) should undertake a curriculum innovation to incorporate

the use of simulations and other computer-assisted instruction that would stimulate learners to construct their own knowledge and improve conceptual understanding of chemistry.

3. The MoE, GES, CRDD and other stakeholders associated with science education should also push for structural modifications in science education to promote the use of computer simulations instructional package and other ICT related instructional tools in the teaching and learning of chemistry and science in general at the SHS level.
4. Practical lessons should be incorporated into the teaching timetables in the schools beginning from form 1 (first year) till final year. This will make room for frequent practical lessons.

5.5 Suggestions for Further Research

Based on the findings and limitations of the study, the following suggestions have been made for further research:

1. It is suggested that the study be replicated for other difficult chemistry concepts, such as, organic chemistry, Chemical kinetics, Redox, among others. This would also provide a basis for greater generalisation of the conclusions drawn from the findings of the study.
2. A study should be conducted to determine the differences between the performances of students from less endowed schools and those from highly endowed schools in organic chemistry

3. Finally, similar empirical studies should be carried out on the use of computer simulations instructional packages on other science subjects and at different levels of science education to provide sound basis for the integration of computer simulations instructional packages in science education in Ghanaian schools.

5.6 Contributions of the study to Chemistry Education

The strength of the study lies in its contribution to chemistry and science education in Ghana. Stakeholders in chemistry curriculum development will acquire useful information from this study that can serve as a basis in incorporating well-structured computer simulation instructional materials and activities in the curriculum whenever there is a change or review of methods of teaching chemistry or science in general.

Chemistry teachers will use the information gained from the study to incorporate computer simulation in their teaching of some of the concepts that look abstract to help concretise such concepts in order to enhance their students understanding.

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APPENDICES

APPENDIX A: PRE-TEST: STUDENTS' KNOWLEDGE IN CHEMICAL BONDING TEST (SKCBT)

PRE-TEST [30 marks] 45 minutes

SECTION A: Circle the correct answer

1. In which of the following is the bonding covalent?
   A. CCl_4 C. NaCl
   B. $MgCl_2$ D. $ZnCl_2$
2. Which of the following bonds is there a complete transfer of electrons during its formation?
   A. Covalent bond C. Ionic bond
   B. Hydrogen bond D. Metallic bond
3. The shape of CH_4 molecule is
   A. Linear C. Pyramidal
   B. Planar D. Tetrahedral
4. The type of bond found in ammonium ion (NH_4^+) are
   A. Covalent and ionic bond C. Ionic and dative
   B. Covalent and dative D. Ionic and metallic bond
5. Organic compounds are important to humans since they
   A. Undergo chemical reactions slowly without catalyst C. Have covalent bonds which undergo reactions easily
   B. Abundance naturally D. Provide clothing, fuel, food and medicine
6. The geometrical shape of the four sp^3 hybridized orbital is
   A. Trigonal pyramid C. Trigonal planar
   B. Tetrahedral D. linear

7. Which of the following will favour the formation of ionic bond between two elements A and B to form AB?
   A. Small electronegativity difference between A and B
   B. High electron affinity of B
   C. High ionization energy of A
   D. Low lattice energy of AB

8. Dative covalent bond results from?
   A. Transfer of electrons
   B. Sharing of elections contributed by one of the participating atoms
   C. Sharing of electrons contributed by both participating atoms
   D. Delocalization of electron

9. Mixing one '**s**' orbital with three '**p**' orbitals results in the formation of
   A. Three sp^2 hybrid orbital
   B. Three sp^3 hybrid orbitals
   C. Four sp^3 hybrid orbitals
   D. Four sp^2 hybrid orbitals

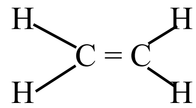
10. Which of the following substances has a giant network structure
   A. Benzoic acid
   B. iodine
   C. Naphthalene
   D. Silicon oxide

11. Which of the following pair bonds are broken in the reaction $H_{2\,(g)} + \frac{1}{2}O_{2\,(g)} \rightarrow H_2O_{\,(g)}$?
   A. O = O and H - H
   B. O = O and O - H
   C. H - H and O - H
   D. O - O and H - H

12. The formation of a pi-bond involves
   A. Head-on overlap of two p-orbitals
   B. Head-on overlap of two s-orbitals
   C. Side-by-side overlap of two s-orbitals
   D. Side-by-side overlap of two p-orbitals

13. What type of bond would be formed between two elements A and B with electronic configurations $1S^2\ 2S^2\ 2P^6\ 3S^1$ and $1S^2\ 2S^2\ 2P^5$, respectively?
   A. Covalent bond
   B. Co-ordinate covalent bond
   C. Metallic bond
   D. Ionic bond

14. A hydrogen compound is represented by the following structure;



Determine the total number of shared pair electrons

A. 12 C. 6

B. 10 D. 5

15. Beryllium chloride ($BeCl_2$) has a linear structure because the hybridization of Be is

A. sp C. sp^3

B. sp2 D. sp^3d

SECTION B

Attempt all questions

1. Define the following;

a. Covalent bond [1 Mark]

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b. Ionic bond [1 mark]

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c. Hybridization [1 mark]

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2. Why do atoms enter into bonding? [1 mark]

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3. Consider $\underline{B}Cl_3$ and $\underline{C}_2H_2$

a. State the type of hybridization shown by the central (underlined) atoms in each of the compounds [2 marks]

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b. State the shapes of the molecules. [2 marks]

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4. How many hybrid orbitals exist in $_6C$. [1 mark]

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5. Explain the following observations: CO_2 is a linear molecule but H_2O is not. (atomic numbers: C=6, O=8) [2 marks]

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6. With the aid of appropriate diagram, indicate how the C = C double bond in alkene is formed. [2 marks]

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7. Distinguish between sigma bond and pi-bond [2 marks]

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APPENDIX B: POST-TEST: CHEMICAL BONDING ASSESSMENT TEST (CBAT)

POST-TEST [30 marks] 60 minutes

Attempt all questions

1. A. Explain with the aid of diagrams the shapes and directions of the ***s*** and ***p*** orbitals [4 marks]

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   B. Name the type of intermolecular forces that exist between CH_4 molecules in liquid methane. [1 mark]

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2. Explain why the boiling temperature of PH_3 is greater than that of CH_4 [3 marks]

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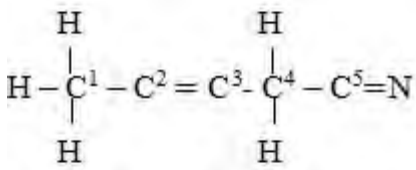
3. Predict the shape of the following molecules, and state their bond angles [5 marks]

   i. $BeCl_2$: ……………………………………………………………………
   ii. BF_3 : ……………………………………………………………………
   iii. CH_4 : ……………………………………………………………………

iv. H_2S: …………………………………………………………………………...

v. NH_4^+ : ……………………………………………………………………………

4. Consider the structure below and state the geometry of the hybridized orbitals C^1, C^2, C^3 and C^4. [2 marks]



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5. With the aid of appropriate diagram, explain how the C = C double bond in alkene is formed. [3 marks]

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6. Explain why the boiling temperature of PH_3 is greater than that of CH_4 [3 marks]

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7. Describe the nature and the formation of the bonding in NaCl. [2 marks]

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8. Explain briefly how the bonds are formed in HCl and Cl_2 are formed [4 marks]

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9. Distinguish between dative-covalent and polar covalent bond [2 marks]

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10. Briefly explain how molecular orbitals are formed and state the types [3 marks]

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……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

APPENDIX C: PRE-TEST STUDENT QUESTIONNAIRE

UNIVERSITY OF EDUCATION, WINNEBA

Department of Science Education

Student Questionnaire

Dear Student,

This questionnaire seeks your opinion about the teaching and learning of Chemical Bonding in your school. Do not write your name, or any other comments that could identify you on this questionnaire. There is no right or wrong answer to any of the questions. This is not a test and your answers will not affect your scores and/or grades. By completing the questionnaire, you are consenting to take part in this research. The information you provide will be useful to improve the instructional methods of teaching and learning chemical bonding. Your answers will remain confidential and any reports about this research will not name any student, teacher or school. Thank you for participating in this study.

SECTION A

Name of School: ……………………………………………………………………..…………

Class Level: [ ] SHS 1 [ ] SHS 2 [ ] SHS 3

Sex: [ ] Male [ ] Female

SECTION B

1. Do you have an interest in studying Chemistry? [ ] YES [ ] NO
2. If YES why? And if NO why? ....

   ....

3. Have you been attending chemistry classes regularly? [ ] YES [ ] NO
4. Do you have practical lessons in chemistry? [ ] YES [ ] NO
5. When are you introduced to practical lessons in your school? [ ] SHS 1 [ ] SHS [ ] SHS 3
6. How frequently do you have chemistry practical? [ ] Once a week [ ] Twice a week [ ] once in a term [ ] No practical
7. Have you been taught chemical bonding? [ ] YES [ ] NO
8. Which teaching method(s) did your teacher use in teaching you chemical bonding? [ ] Lecture method [ ] Practical and discussion method [ ] Demonstration method [ ] Lecture and Discussion method [ ] Discussion method [ ] Other
9. Which teaching method would you prefer your teacher to use in teaching chemical bonding? [ ] Lecture method [ ] Practical and discussion method [ ] Demonstration method [ ] Lecture method Discussion [ ] Discussion method [ ] Other
10. Does your teacher integrate ICT in the teaching of Chemical bonding in your school? [ ] Yes [ ] No
11. Does your teacher use Computer Simulation Instructional Methods in the teaching of Chemical Bonding in your school? [ ] Yes [ ] No
12. Do you have skills in the use of computers? [ ] Yes [ ] No
13. As a student, what is your main focus as you study chemistry in school? [ ] To pass WASSCE [ ] To have a better understanding of the subject matter

[ ] To have a better understanding of the subject and be able to apply its principles in life [ ] Other……………………………………………………………………..

…………………………………………………………………………………………

14. How do you think the teaching and learning of Chemical Bonding can be improved in your school?

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

APPENDIX D: RELIABILITY STATISTICS OF THE RESEARCH INSTRUMENT

Reliability Result of the Pilot Study

Reliability Statistics	
Cronbach's Alpha	0.67
Cronbach's Alpha Based on Standardized Items	0.73
N of Items	14.00

APPENDIX E: DETERMINATION OF THE DEGREE OF SIGNIFICANT IMPROVEMENT IN STUDENTS PERFORMANCE

From Table 4.3, the following calculations are computed

Difference in performance of the Control Group

DPC = MP2 – MP1

Where DPC = mean difference in score in the Control Group

MP1 = mean score of Pre-test

MP2 = mean score of Post-test

DPC = 20.00 – 18.17

DPC = 1.83

Percentage DPC = $\frac{DPC}{Total\ Score} \times 100\ \%$

Percentage DPC = $\frac{1.83}{30} \times 100\ \%$

Percentage DPC = 6.1%

Difference in performance of the Experimental Group

DPE = MP2 – MP1

Where DPE = mean difference in score in the Experimental Group

MP1 = mean score of Pre-test

MP2 = mean score of Post-test

DPE = 24.24 – 18.27

DPE = 5.97

Percentage DPE = $\frac{\text{DPE}}{\text{Total Score}} \times 100\ \%$

Percentage DPE = $\frac{15.97}{30} \times 100\ \%$

Percentage DPE = 19.9%

Degree of Significant Improvement in the Experiment Group Over the Control Group

DSI = DPE – DPC

Where DSI = Degree of significant improvement

DSI = 19.9 – 6.1

DSI = 13.8 %

APPENDIX F: MARKING SCHEEME FOR PRE-TEST

STUDENTS' KNOWLEDGE IN CHEMICAL BONDING TEST (SKCBT)

MARKING SCHEME [30 marks]

Objective

1. A	2. A	3. D
4. B	5. B	6. B
7.B	8. B	9. C
10. D	11. A	12. D
13. D	14. C	15. A

SECTION B **Answers**

8.

a. **Covalent bond:** It is the sharing of electron pair between two atoms in which each atom contributes an electron for sharing **[1 mark or Zero]**

b. **Ionic bond:** It is formed between two atoms when there is complete **transfer of valence electron** from one atom to another OR

It is an **electrostatic force** of attraction between the **positively charged ion and a negatively charged ion**. **[1 mark or Zero]**

c. **Hybridization:** It is the **mixing up** of two or more **different atomic orbitals** of different energy and shape to form new **hybrid orbitals** of same/ equivalent energies and shape. **[1 mark or Zero]**

9. To attain stable electronic configuration/ octet/ duplet structure [1 mark]
10. To attain stable electronic configuration/ octet/ duplet structure [1 mark]

11.

a. BCl_3 - SP^2 hybridization **[1 mark or Zero]**

C_2H_2 – SP hybridization **[1 mark or Zero]**

b. BCl_3 - trigonal planar or triangular **[1 mark or Zero]**

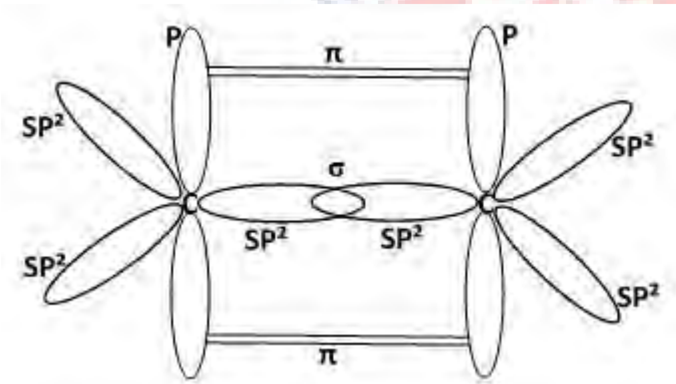
C_2H_2 – linear **[1 mark or Zero]**

12. Three (3) types of hybrid orbitals $_6C$ (i.e. SP, SP^2, SP^3) **[1 mark or Zero]**

13. In CO_2, the carbon is SP hybridized. **[1 mark or Zero]**

In H_2O, the Oxygen is SP^3 hybridized. **[1 mark or Zero]**

14.



Each carbon atom forms there sp^2 hybrid orbitals. Each carbon uses one of its sp^2 hybrid orbital to overlap axially with each other adjacent to form a sigma bond. This shortens the internuclear distance between the two carbon atoms each containing an electron to overlap sideways to form the second bond called the pi, π-bond.

Shape is trigonal planar and bond angle is 120° **[2 marks]**

15. Difference between sigma bond and pi-bond

Sigma bond	**Pi-bond**
Head-on overlap of atomic orbitals	Lateral overlap of 2 P orbitals
Less reactive	More reactive
Stronger bond	Weaker bond
Bonding electrons are localized	Bonding electrons are delocalized

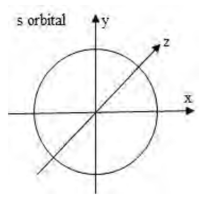
Any 2 x 1 = 2 marks

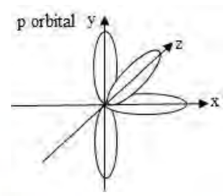
APPENDIX G: MARKING SCHEME FOR CBAT

CHEMICAL BONDING ACHIEVEMENT TEST (CABT)

POST-TEST [30 marks]

1. A. Shapes and directions of the ***s*** and ***p*** orbitals





Shape is spherical in space Non-directional
S-orbitals only differ in radii

P-orbital made up 3 orbital which are directed towards x, y and x axes.
The 3 p orbitals are perpendicular to each other

[2 marks for diagram; 2 marks for explanation]

B. The intermolecular forces in CH_4 molecules in liquid methane is van der Waals ***[1 mark]***

2. Why the boiling temperature of PH_3 is greater than that of CH_4

PH_3has a dipole-dipole between molecules but CH_4 has no net dipole despite ***[1 mark]*** the individual polar C-H bonds. Inter molecular forces is therefore stronger in PH_3 than in CH_4. ***[1 mark]***

3. Shapes and bond angles

i. $BeCl_2$: shape is linear, bond angle is 180^o ***[1 mark]***

ii. BF_3 : shape is trigonal planar, bond angle is 120^o ***[1 mark]***

iii. CH_4 : shape is tetrahedral, bons angle is 109^o ***[1 mark]***

iv. H_2S: shape is trigonal pyramidal, bond angle is 107° ***[1 mark]***

v. NH_4^+ : shape is tetrahedral, bond angle is 109° ***[1 mark]***

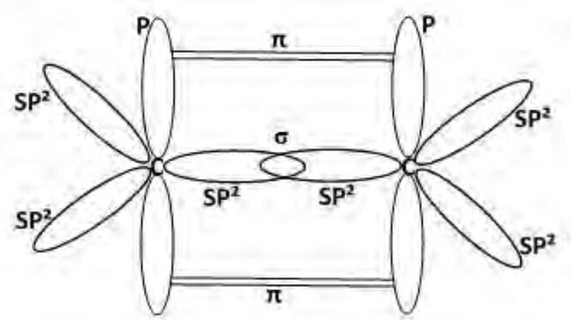
4. The geometry of the hybridized C orbitals

[2 marks]

$C^1 = sp^3$ $C^2 = sp$ $C^3 = sp$ $C^4 = sp^3$

NB: N is sp hybridized [$\frac{1}{2}$ mark each : Total 2 marks]

5. The formation of C=C bonds in ethane



Each carbon atom forms there sp^2 hybrid orbitals. Each carbon uses one of its sp^2 hybrid orbital to overlap axially with each other adjacent to form a sigma bond. This shortens the inter-nuclear distance between the two carbon atoms each containing an electron to overlap sideways to form the second bond called the pi, π-bond.

Shape is trigonal planar and bond angle is 120°

[Diagram 1, correct labelling and locations of bonds 1 mark, explanation 1 mark]

6. **Hydrogen Bond** is a weak electrostatic force of attraction between a hydrogen atom attached to a highly electronegative atom in one molecule of a compound and a lone-pair of electrons of an electronegative atom in another molecule. [***2 marks or 0***]

7. **Nature and formation of NaCl**

NaCl shows ionic bonding

Na of low IE loses an electron from the outermost shell (3s1) to become a cation and thereby attains an octet structure. The Cl atom of high electron affinity gains the electron onto its 3p5 orbital to form a singly charged anion. The two oppositely charged ions are attracted to each other by ionic forces to form the ionic bond.

[2 marks or 0]

8. **How bonds in HCl and Cl_2 are formed**

Cl_2: the bonding is covalent and results when the atomic orbitals of the two chlorine atoms each containing an unpaired electron overlap and then share the pair of electrons. ***[2 marks or 0]***

HCl: has a polar covalent bond

The atomic orbital of H overlap with those of Cl. H and Cl contributes an electron each and the pair of electron are then shared between the two atoms to achieve stable inert gas structure. Because Cl is more electronegative than H, it pulls the shared paired of electrons more unto itself. Cl attains a partial negative charge at its end whiles H attains a partial positive charge at its ends. Hence polar covalent bond is formed between H and Cl. ***[2 marks or 0]***

9. **Difference between dative-covalent and polar covalent** bond

Dative covalent bond is a bond formed by the sharing of a pair of electrons in which both electrons are donated by only one of the bonding atoms

Whiles

Polar covalent bond is a type of bond formed when there is unequal sharing of electron pair between two atoms as a result of the differences in the electronegativities of the bonding atoms. [2 or 0]

10. Formation of molecular orbitals

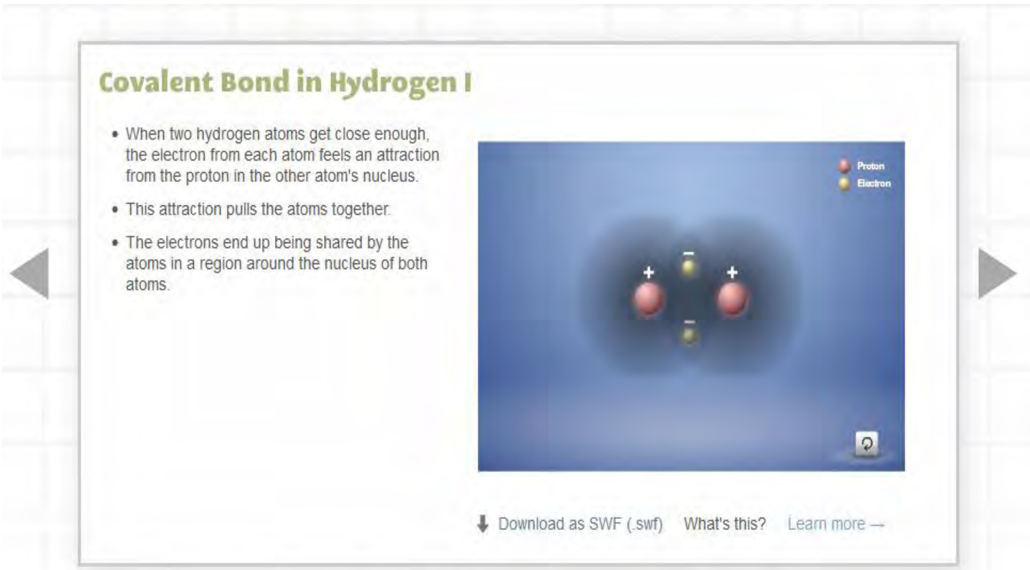
Molecular Orbitals are formed as a result of the overlap of two atomic orbitals each containing an unpaired electron. This leads to the formation of covalent bond.

[***2 marks or 0***]

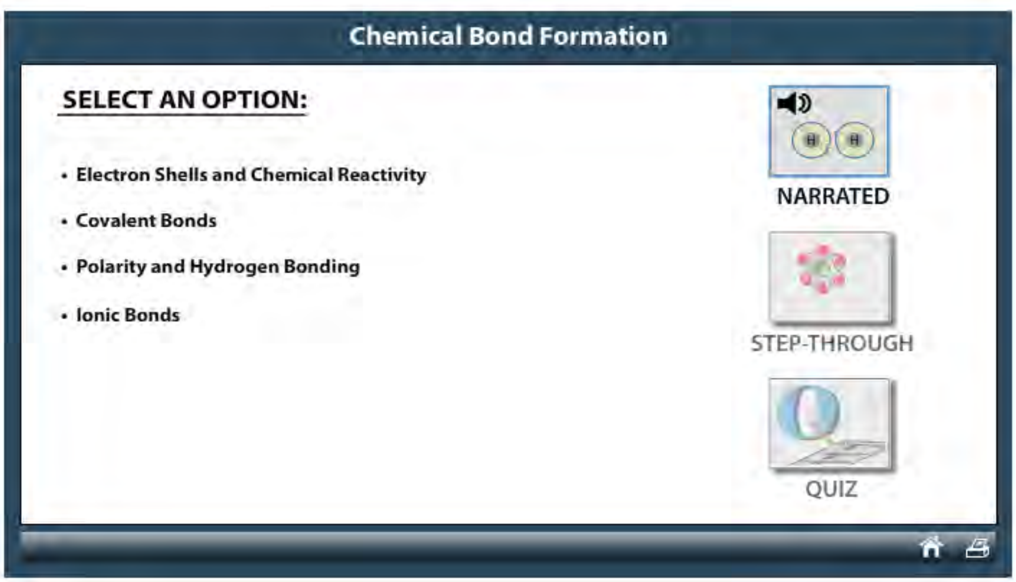
Types of molecular orbital

- ✓ Sigma molecular orbital (Sigma bond) [$\frac{1}{2}$ mark or 0]
- ✓ Pie molecular orbital (pi bond) [$\frac{1}{2}$mark or 0]

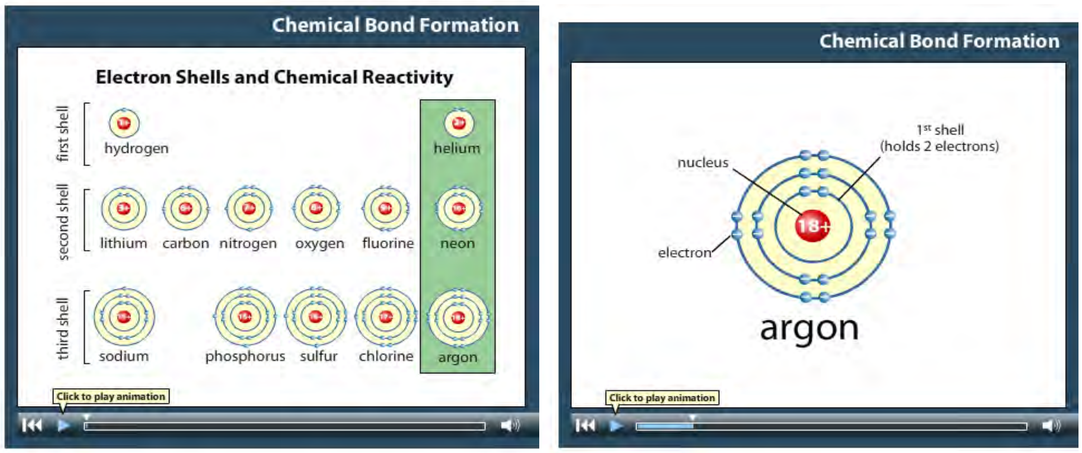
APPENDIX H: SCREEN SHOT OF SOME OF THE SIMULATIONS USED IN THE STUDY



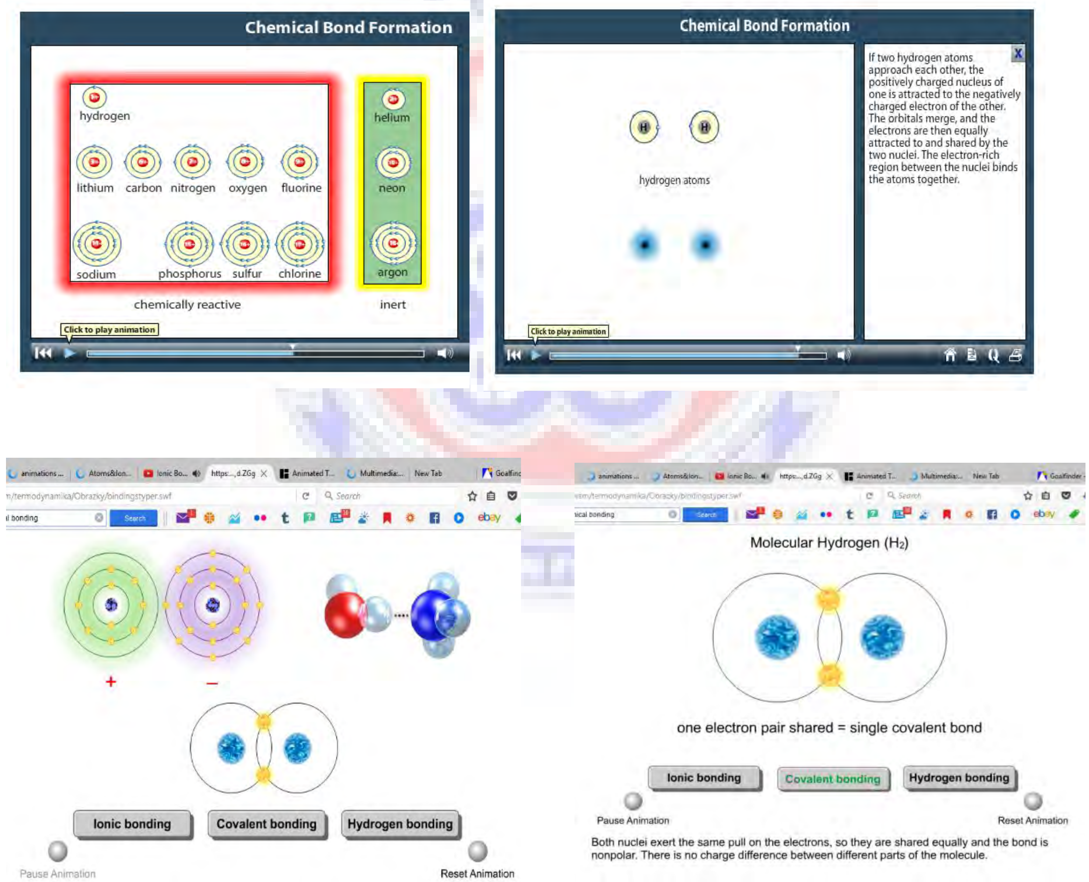
A simulation showing covalent bonding in Hydrogen



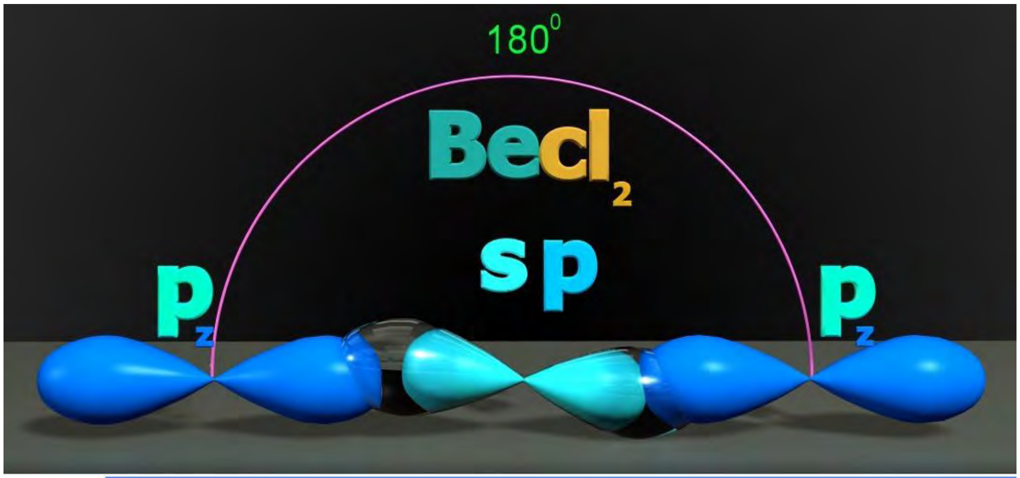
A screenshot of simulation lesson on Chemical Bond formation



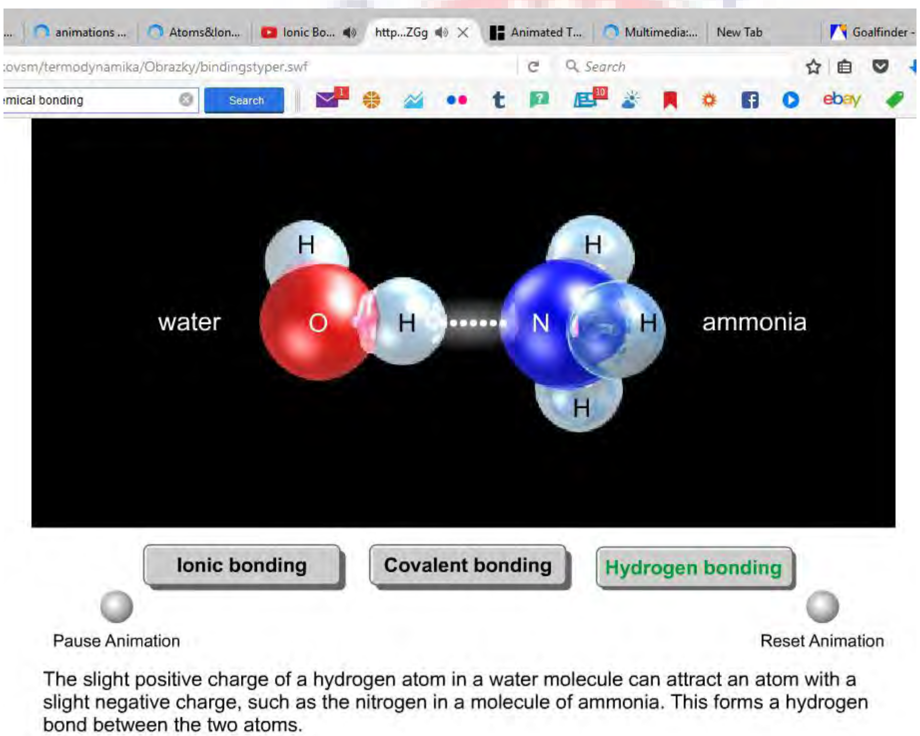
A screenshot simulation of Chemical Bond formation



A screenshot of a simulation showing the covalent bond in molecular Hydrogen



A screenshot of a simulation showing the formation of $BeCl_2$



A screenshot of a simulation showing the Hydrogen bond between water and ammonia