EFFECTS OF INSTRUCTIONAL SOFTWARE PACKAGE ON STUDENTS' ACHIEVEMENT AND INTEREST IN CHEMICAL BONDING

BY

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A THESIS PRESENTED TO THE DEPARTMENT OF SCIENCE EDUCATION, UNIVERSITY OF NIGERIA, NSUKKA, IN FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF DEGREE OF DOCTOR OF PHILOSOPHY IN SCIENCE EDUCATION (CHEMISTRY)

DEPARTMENT OF SCIENCE EDUCATION
UNIVERSITY OF NIGERIA, NSUKKA

OCTOBER , 2014

APPROVAL PAGE

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CERTIFICATION

I, OKORIE, EUGENE UCHEYA, a postgraduate student with registration number **PG/Ph.D/09/51251** hereby certify that this thesis is entirely a result of my independent research and it has not been presented either wholly or partly for any degree and is not being concurrently submitted for any other degree in this or any other university. The various sources to which I am indebted are clearly indicated in the reference.

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OKORIE, EUGENE UCHEYA

DEDICATION

This work is dedicated to my children: Joy Chinememma Oriaku Ruthmary, Chimeremomiko Nkechi Madonna and Emmanuel Chimeucheya Okorie; and all Nigerian children for whom I desire, labour and pray that they may be bequeathed a better education system.

ACKNOWLEDGEMENTS

I thank the Supreme God, the giver of life and knowledge through my Lord and Saviour Jesus Christ without who I am nothing, for His mercies, protection, privilege, opportunity and strength to complete this study.

In the course of this study, a number of individuals played significant roles towards its successful completion. It is therefore with profound gratitude and immense appreciation that I thank them all. In a special way however, I single out and acknowledge with thanks, the keen interest and assistance of my supervisor, Prof. D. N. Ezeh, whose friendly disposition, suggestions, guidance and willingness to be available any time for consultation helped in successful and speedy completion of the study. Besides giving constant prod, he gave me free access to his personal library. In sincere appreciation, I thank Prof. P. N. Okeke, former Director, NASRDA Centre for Basic Space Science CBSS, Nsukka whose encouragement, advice and generosity allowed me the use of his personal and the CBSS library facilities. I am indebted to Prof. B. G. Nworgu for his words of encouragement. I thank Prof. Z. C. Njoku who followed me with keen interest and advice as I made progress on the study. Dr. B. C. Madu gave me an invaluable advice at a crucial moment.

I equally thank Dr. J. C. Adigwe who followed every phase of the study and brought his wealth of knowledge in research and chemical education to bear on the study. His critical but constructive criticisms helped to shape and bring out the best ideas in me. In addition, I wish to acknowledge Prof. K. O. Usman who made comments and suggestion that enabled me to improve the quality of the main product of this study. In a particular way, I thank Mr. Ambition Okwarajiaku and Mr. Emmanuel Nwangwu for their technical assistance in making the product of this study a reality. These gentlemen left their expertise and experience at my disposal for tapping into during several construction works on the software package, the product of the study.

I thank Prof. U. M. Nzewi whose style of administration as Director of CUDIMAC (where my office during the course of this study was located), created a conducive atmosphere that enabled me to progress and complete this study at a faster rate. I thank Drs C. R. Nwagbo, F. O. Ezeudu, Ebere Ibe and Francis Akubuilo for their words of encouragement. I thank the Principal, staff and students of all the schools used in this study for their cooperation.

I am deeply indebted to my wife, Veronica Nnenna and children, who had to forgo basic comfort and enjoyed less of my presence at home so that this study could be completed.

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ABSTRACT

The study investigated the effects of an instructional software package – Chemical Bonding Instructional Software Package (CBISP) - on secondary school students' achievement and interest in Chemical Bonding. It also investigated the influence of gender and location on students' achievement and interest in Chemical Bonding when the instructional software was used. The design of the study was a pretest-posttest non-equivalent control group design. The population consisted of 5,966 senior secondary class one (SS1) chemistry students. The sample consisted of 311 SS1 students drawn from nine senior secondary schools in Nsukka Education zone. The criteria for selecting the schools in the study were based on availability of ICT facilities such as computer and over head projectors; ability of teachers to perform basic operations using the afore mentioned ICT facilities; school location (urban and rural) and gender of students. The instruments for the study were Chemical Bonding Achievement Test (CBAT) and Students' Interest Scale on Chemical Bonding (SISCB). Two university chemical educators, one measurement and evaluation expert and six professional secondary school chemistry teachers validated the instruments. The reliability of CBAT was 0.87, calculated using Kuder Richardson formula 20.The reliability of SISCB was 0.68, calculated using Cronbach Alpha method.

Twelve research questions guided the study and fourteen hypotheses were tested at p = 0.05.The researcher trained regular chemistry teachers of the selected schools for experimental group for one week, on instructional software method (ISM). For the control group, the Traditional lecture method (TLM) was used. In this case, only the Course of Study on Chemical Bonding (CSCB) was used. The CSCB is a hardcopy and has the same text materials and illustrations as in the software. Intact classes were used. Treatment for the study was teaching, using ISM, and this lasted for five weeks. ISM involves guiding the students and making necessary explanation to them on request while learning, using the CBISP. Before treatment commenced, the researcher administered CBAT and SISCB to the subjects as pre-tests. Each of the tests lasted for 40 minutes. The subjects' scores in the tests were recorded and kept separately. Three periods of 40 minutes each week were used for teaching of the students, following the usual school timetable as was peculiar to each school. The next day, immediately after the completion of treatment, the researcher administered CBAT and SISCB to the students as post-test and their scores were recorded separately. For this post-test, the various questions in CBAT were rearranged to eliminate the effect of familiarity with the items in the instruments. Each of the tests lasted for 40 minutes. Analysis of covariance (ANCOVA) was used in this study. The covariates are the pre-test and post-test (CBAT) and SISCB scores. Mean and standard deviation scores were used in answering the research questions. From the data analyses, the following results emerged: Method of teaching has statistically significant effect on students' mean achievement in chemical bonding ($F= 16.10$, $p < 0.05$); gender has no statistically significant influence on students' achievement in chemical bonding ($F = 3.23$, $p > 0.05$); school location has statistically significant influence on students' mean achievement in chemical bonding ($F = 4.24$, $p < 0.05$); the interaction effect of gender and location on students' achievement in chemical bonding is significant ($F = 12.19$, $p < 0.05$); the interaction effect of gender and teaching methods on students' achievement in chemical bonding is significant ($F = 72.84$, $p < 0.05$); the interaction effect of location and teaching methods on students' achievement in chemical bonding is significant ($F = 72.37$, $p < 0.05$); gender has no statistically significant influence on students' interest in chemical bonding ($F = 2.98$, $p > 0.05$); school location has no statistically significant influence on students' interest in chemical bonding ($F = 1.15$, $p > 0.05$); method of teaching has statistically significant effect on students' interest in chemical bonding ($F = 4.24$, $p < 0.05$); the interaction effect of gender and school location on students' interest in chemical bonding is not significant ($F = 0 .37$, $p > 0.05$); the interaction effect of gender and teaching methods on students' interest in chemical bonding is significant ($F = 5.53$, $p < 0.05$); the interaction effect of school location and teaching methods on students' interest in chemical bonding is not significant ($F = 0 .29$, $p > 0.05$).

The educational implications of these findings were discussed. Based on these findings, the following recommendations among others were made: chemistry teachers should be encouraged to use ISM in teaching chemical bonding. Enrichment of chemistry teacher-training programmes in Nigerian teacher-training institutions and faculties, to include appropriate ICT courses that enable teachers develop and use their own-made instructional software packages, to make their teaching effective. The limitation of the study was discussed and suggestions for further studies were made.

CHAPTER ONE

INTRODUCTION

Background to the Study

Computer-aided instruction and learning (CAIL) is an aspect of e-learning, which is the current trend in pedagogy. Other aspects of e-learning include web-based learning. CAIL is recommended in most 21st century secondary schools chemistry curriculum of many countries, including Nigeria (NERDC, 2009). On daily basis, students use the computer to surf the Internet for various educational information and activities; to play games, send and receive mails, chat with friends, create or update their own blogs and carry out other activities of interest to them. The computer has become not only a means of entertainment but also a veritable instrument of learning for present day students at all ages (Ayogu, 2011). Olayiwole (2005) advocated the use of ICT, particularly computer in teaching chemistry in Nigerian schools. The author asserted that some chemistry contents are better taught using the computer.

Chemistry has been described as the science of molecules and their transformation (Hoffmann, 1991), and is pivotal to the transformation and development of many nations. Developed nations are associated with numerous and varied industries (both light and heavy), involved in processing materials (inorganic and organic substances) including oil, gas, petrochemicals, textile, food, pharmaceutical and ceramic industries. Transformation and development of any nation are tied to the presence of heavy chemical industry, which meets economic and defence requirements.

An important constituent of the chemical industry is manufacturing or industrial processes based on achievements in chemistry (Potapov and Tatarinchik, 1979). Manufacturing or industrial processes are procedures involving chemical or mechanical steps to aid the manufacture or production of specific materials or items, usually carried out on a large scale. They include those in industry of heavy (basic) organic synthesis, which produces hydrocarbons of various types used as raw materials for other industries involved in secondary processes, for example, oxygen-containing organic compounds (alcohols, aldehydes, ketones, acids, ethers and esters); nitrogen-containing organic compounds (nitro compounds, amines, nitrides); halogen-containing organic compounds; and substances containing phosphorous, silicon and other elements.

Besides organic synthesis, chemistry plays a key role in the production of fuel cells, refrigerators, heat pumps, and engines the functions of which are based on the second law of thermodynamics studied under physical chemistry. Other products based on application and knowledge of physical chemistry include laser rays used in reading barcodes and compact discs (CDs) (Engel and Reid, 2006).

Chemistry as pivotal to the transformation and development of nations has continued to play an increasingly important role in the production of many technologies, from life-saving pharmaceuticals to computers and other information technologies. Because of the central role it plays in the successful study of science-based courses such as medicine, pharmacy, biochemistry, engineering, agriculture and several others, chemistry is regarded as a 'central science' and this underlines the importance and need to study it. Chemistry and its impact on lives of individuals will continue to grow, and probably even at a faster rate in the 21st century, as a number of innovative secondary school chemistry curricula have emerged across the globe since the turn of the 21st century.

In Nigeria efforts being made by various stakeholders to improve chemical education attest to the general awareness that chemistry plays a significant role towards its national transformation and development. For instance, at the tertiary level of Nigeria's education system, virtually all private and public institutions of higher learning have academic departments for the study of chemistry and chemistry-related courses. The various proprietors of these institutions provide laboratory facilities for the study of chemistry. Besides the huge budgetary allocations made to these institutions for the purchase of chemicals and equipment, the Federal government has built science equipment manufacturing centres in Enugu, Minna and Lagos for local fabrications of equipment needed to study chemistry and other science subjects. At the secondary level of education, various state governments have built special science schools; proprietors of secondary schools and others, including individuals build and equip chemistry laboratories while science allowance is paid to teachers of chemistry and other sciences as incentive to encourage the teachers to put in their best in ensuring that students are well taught.

In spite of its importance and the efforts to improve chemical education in Nigeria, achievements of secondary school students in chemistry have continued to fall bellow expectation (Adeyegbe, 1998; Ifeoma, 2005; Agbi, 2006, Udo & Eshiet, 2007 and Nwahunanya, 2011). One of the reasons for this poor state of affair is attributed to poor foundation in the students' early years of studies in chemistry, resulting from among other factors, inappropriate teaching methods adopted by teachers (Adeyegbe, 1998; Nwofor, 1991; Ochu, 2007; Udo & Eshiet, 2007 and Nwahunanya, 2011). The teachers seem not to have adequate knowledge and skills in their choice of teaching methods and usage of appropriate instructional strategies for meaningful teaching (Oloyede, 1998; Agbi, 2006; Ayogu, 2011; Agogo & Terngu, 2011). The teachers use mainly lecture method with no recourse to the use of relevant instructional materials and practical activities that arouse and sustain students' interest in the subject or concept. This mode of teaching does not make lessons lively, and does not help in concretising abstract ideas often associated with many chemical concepts. This perhaps accounts for the learning difficulties (Udo & Eshiet, 2007 ; Oloyede, 1998; and Nwahunanya, 2011) that students have about chemical concepts. One of such chemical concepts, which students find difficult is chemical bonding (Peterson, Treagust and Garnett, 1986; Butts and Smith, 1987; Boo, 1998; Pereira and Pestana, 1991; Griffiths and Preston, 1992; and Nwahunanya, 2011).

Udo and Eshiet (2007) defined difficult chemical concepts as those that teachers find difficult to teach or students find difficult to understand. This is the case with chemical bonding. Nwahunanya (2011) asserted that secondary school teachers find it difficult to teach chemical bonding . The chemical bond is at the heart of chemistry and bonding between atoms is the essence of chemistry (Engel and Reid, 2006). In other words, understanding chemical bonding and the nature of the bonds is very fundamental in the study of chemistry. For example, a good understanding of bonding and the nature of bonds makes it easy for chemistry students to predict the overall energy change in a chemical reaction (Boo, 1998). WAEC (2010) showed that candidates in Senior School Certificate chemistry examination were unable 'to correctly distinguish between dative bond and covalent bond'. A covalent bond is one in which two atoms share a pair of electrons. A dative bond is just like any other covalent bond once it has been formed. The only difference is that one atom, rather than each atom donating one electron donate both electrons. It is perhaps in consideration of the difficulties that students have in understanding; and their inability to explain for example the concept of dative bond and covalent bond, as explained above, that Oloyede (1998) concluded that learning of some chemical concepts by most Nigerian secondary school students is generally regarded as difficult.

Lasisi (1998) asserted that a recipient of chemical education in Nigeria ‘merely “adsorbs” and “desorbs” scientific facts’, with the result that they lack operational and manipulative skills needed for meaningful application of theoretical concepts to real life situations. Ifeoma (2005), blamed students’ learning difficulties and low achievement in chemistry on the different teaching methods (lecture, discussion, guided discovery, expository, etc.) employed in teaching chemistry to the students. The percentage of failures in this subject at the school certificate examination has consistently remained large (Okorie, 1983; Lasisi, 1998; Adeyegbe, 1998; Ajah, 2004; Agbi, 2006; Ochu, 2007). This secondary school students’ low achievement in chemistry has persisted as shown in Table 1. This is worrisome, in view of the central role of chemistry in the study of science-based courses.

Table 1: Students' Performance in SSCE Chemistry (2004 – 2010)

Year	Total Entry	Total Sat	% Performance Grade 1-6	% of Failure	Passes (P7)	(P8)
2004	334491	3275503 (97.91)	37.86%	32.76%	3.26%	12.26%
2005	357658	349936 (97.54)	50.94%	27.28%	8.65%	10.06%
2006	389462	380104 (97.84)	44.90%	30.11%	10.47%	12.76%
2007	432230	432230 (100)	45.96%	26.33%	13.85%	13.85%
2008	428513	418423 (97.65)	44.44%	26.39%	10.43%	10.98%
2009	478235	468540 (97.97)	43.69%	25.45%	10.48%	13.85%
2010	477573	465643 (97.50)	50.70%	21.08%	10.81%	12.80%

Source: West African Examination Council (WAEC) Statistics Division, (1990 – 2010), *Statistics Annual Report of WAEC Exam,*5,L/PR/92,PP:71,74,78,104. Yaba, Lagos: Megarons (W.A) Plc.

It appears that these traditional methods of presenting chemical concepts to beginning students, at the secondary school level, do not encourage or engender adequate understanding of the concepts; and so constitute serious problem that might have led to a decline in achievement among students who study chemistry.

Achievement of students has often been associated with their gender. Gender refers to the fact of being male or female (Pearson Education, 2003). Kanno (2008) referred to gender as an analytic concept that describes sociological roles, cultural responsibilities and expectations of men and women in a given society or cultural setting. Therefore, gender is a psychological term and a cultural construct developed by society to differentiate between the roles, behaviour, mental and emotional attributes of males and females. Eze (2008) asserted that gender had significant effects on students' achievement in chemistry, and showed that male students achieved higher than their female counterparts did. Owoyemi (2007) asserted that student's achievement in chemistry course has 'nothing to do with whether the student is male or female'. Other studies (Ssempala, 2005; Adesoji and Babatunde, 2008) showed that there is difference in performance among male and female students in chemistry. Adigwe (1992) showed that male students perform better than female students in both achievement and acquisition of problem solving skills. There is therefore the problem of uncertainty about the influence of gender on achievement in chemistry. In other academic discipline, Bosede (2010) showed that there is no difference in performance of students because of gender. The influence of gender on learning and achievement has remained a controversial and topical issue amongst educationists. Therefore, there is need in this study to investigate the effect of gender on students' interest and achievement in chemical bonding.

Teaching method appears to contribute significantly to the problem of low achievement among secondary school chemistry students. Oriaifor (1993) attributed students' low achievement in chemistry to a function of several factors including the proficiency of the teachers, teaching method which in Nigeria is 'still largely based on abstract exposition and learning done by rote memorisation'. Therefore, the present methods of teaching chemistry, especially the traditional method of teaching chemical bonding can be said to encourage rote learning on the part of the students. This is the crux of the matter.

Oriaifor (1993) therefore suggested that in seeking solutions to the problems of underachievement of students, efforts should be made towards 'finding answers to the problems of teaching method applied in chemistry'. Lasisi (1998) observed that teaching of chemistry in secondary schools has become too rigid, didactic and expository and that this traditional method of teaching chemistry limits effective understanding of chemical concepts to the students. In chemistry education particularly, the inability of the teacher to communicate effectively the meaning of chemical concepts represented by the signs, formulae or structure has been found to affect students' achievement in chemistry. Adeyegbe (1998) reported that the teachers' ineffectiveness in communicating the concept of chemical bond to chemistry students resulted in the students' average achievement of 31% on the test based on the concept. Ineffective communication between the teacher and students in a chemistry class makes the lesson uninteresting. Ogunsola-Bandele (1998) asserted that ineffective communication between the teacher and students in chemistry class results from inappropriate teaching strategy adopted by the teachers, who often presents chemical concepts as they were presented to them several decades back.

There is the need, therefore, to explore other intervention teaching strategies to improve achievement in the subject amongst secondary school students. The intervention teaching strategy should be one that explores and takes advantage among others, of the students' background in terms of previous knowledge and interest in the subject, in improving their learning. Oriaifor (1993) recommended the adoption of the 'eclectic methods which combine essential components of the traditional lecture method with those of the progressive'. It is in this spirit of progressiveness that McKee (1997) suggested that progressive teachers would seize any available opportunity to integrate appropriate multimedia into the learning environment. Progressive teachers are teachers with new or modern ideas and methods in education who want to change things. One of such progressive approaches to pedagogy is the Computer Assisted Instruction (CAI) or e-learning, which is recommended in most 21st century secondary school chemistry curriculum of many countries including Nigeria.

In educational institutions therefore, the computer is recognised as a very vital instrument for teaching and learning (Ebem & Inyama, 2005; Okoroafor & Okoroafor, 2010; Ayogu, 2011). Ebem & Inyama (2005) asserted that the computer provides a multimedia learning system – a technology based learning system that combines use of written words, images, sound, video, animation and interactive conversation to transmit information and enhance the process of teaching and learning. They suggested that the computer's role in education is that of educational medium. Ayogu (2011) noted that the computer provides interactive hands-on and minds-on activities that stimulate and facilitate critical thinking, creativity and problem-solving skills.

It is therefore understandable why institutions of learning, teachers and curriculum planners now place emphasis on computer-assisted instruction and computer-assisted learning. In fact, all over the world, the various chemistry curricula that have emerged since the turn of the 21st century for the study of the subject at the secondary school level offer new ideas about how teachers should deliver chemistry concepts, using new technologies and devices (the Internet, computer-based classroom projection tools), to assist students in learning (Okorie, 2010). For example, the Nigerian Educational Research and Development Council (NERDC) Curriculum for Senior Secondary School Chemistry (NERDC, 2009) recommends that as part of their learning activities, students should surf the Internet for information, for example, on chemical industries, and the uses of Nitrogen. The same curriculum recommends the Internet, hence the computer as a teaching tool to teachers in delivering their lessons (NERDC, 2009).

The computer is seen as an important, wonderful, intelligent, and versatile machine, and very often, it is not realised that these attributes of the computer depend on the computer software, without which it becomes impossible for the computer machine to carry out any operation (Mbam, 2005). The software is a set of programs necessary to carry out operations for a specific job. These programs consist of step-by-step instructions telling the computer how to carry out operations for a specific job (Gupta, 2008). The computer software's ability to interface and interact very well with the computer hardware accounts for these attributes associated with the computer. Therefore, meaningful computer operations can only take place when the computer software is available in the computer machine.

The computer software constitutes the non-physical or tangible component of the computer system. It is the logical mechanism that enables the computer user to harness the computing potential, which modern computer hardware represents (Mbam, 2005). It is the software that gives a computer the intelligence it possesses (Nwakalo, 1995), and the flexibility and versatility to do whatever the user wants (Ngene, 1999). Li-Yeh, Cheng-Huei and Cheng-Hong (2001) noted that one software package might have different facets through which to interact with users, and software designers typically select ways of displaying the features of a particular software package in a manner appropriate to its theme and purpose, in order to ensure the best possible educational results. Using application program and a software package specifically designed for that purpose, the computer provides a forum for a two–way dialogue, with the learner in a position to determine both the scope and level of the dialogue.

The acceptance of the computer as a vital instrument for teaching and learning in the 21st century implies that relevant Instructional Software packages to teach specific lessons need to be developed for computer-assisted instruction and learning, especially for difficult and abstract concepts such as chemical bonding. Mbam (2005) and Ekoko (2006) point to the scarcity of relevant software packages and the need to develop them for Nigerian educational system. Such software packages should consider the characteristics, interests, educational needs of students, the curricular needs to be addressed and should be free from programming errors or 'bugs'. Computer-assisted instruction is a set of programs written to stimulate learning process. It also serves as a teaching tool. It is a learning process, in which a student interacts with, and is guided by a computer through a course of study aimed at achieving certain instructional goals. Through computer-assisted instruction, computers can become a very powerful instrument that would assist the chemistry teacher in effectively managing large-size classes, which have become one of the major problems that confront secondary school classroom teachers in Nigeria, where there is a dearth of good and professionally qualified chemistry teachers (Okorie,1986; Nwofor,1991; Oloyede, 1998).

Computer-assisted instruction helps in restructuring learning environment by engaging the students with computers, through which the learners receive instructions on the screens and make appropriate responses through the attached keyboards. Depending on the learner's responses, the stored programme in the computer varies its sets of instructions to meet individual learners' needs. Mbam, Ekwe and Ituma (2005) observed that computer-assisted instruction can be made available all day long; and to many students through time sharing, as the computer has the capacity to drill them while each student works privately at his/her own pace. The computer is a patient teacher and it can repeat a given exercise several times without being bored; this is a unique quality that may not be associated with a human teacher. The relationship between the computer and the student is impersonal; therefore, a student can afford to make mistakes without fear of embarrassment. In its assessment of students' learning, the computer-assisted instruction is impartial; this is an advantage that may not be guaranteed with a human teacher.

In consideration of the unique role, which chemistry plays in the live of individuals and society, Oriaifor (1993) observed that the objective of instruction in chemistry is normally to produce cognitive learning as well as impart to the students among others, scientific attitudes and interest that bring about positive changes in the students' behaviour. Gankon (1998) defined scientific attitude as the position taken by an individual relative to feelings, thinking, prejudice or bias, preconceived notions, ideas, fears, etc. Attitude influences students' achievement, interest, attention, motivation and confidence in learning (Keeves, 2002; Olatunde, 2009 and Bot, 2011). It is necessary that teachers help their students to develop the right kind of attitude in classrooms. The Oxford Dictionary defines interest as the feeling of wanting to give your attention to something or of wanting to be involved with and to discover more about something. Pearson Education (2003) explains that if an individual has interest in something, that individual wants to know or learn more about them. Thorndike and Hagen (1969) defined interest as the tendency to seek or avoid particular activities.

From the above definitions and explanation, interest is emotional expression of like or dislike towards an object or activity. It is a trait, which could be aroused in someone. For instance, interest in a subject or the use of a particular tool could be aroused by sheer advert, that is, telling someone how useful and helpful the subject or tool could be towards achieving a particular objective. In this case, the cultivation, development and sustenance or otherwise of interest in the subject or tool will depend on how truly useful the subject or tool has helped in achieving a desired objective or in performing a particular function.

Interest enables someone to make a choice between alternatives; the individual 'makes a variety of choices with respect to the activities he engages. He shows preferences for some, aversion to others' (Thorndike and Hagen, 1969: 27), for example, in the use of two alternative pedagogic approaches in achieving the same educational objectives. Agbi (2006) asserted that interest determines the vigour, which a learner invests in learning and other activities. This implies that the degree of interest in a particular object, situation or activity can only be ascertained in actual involvement of someone with the object, situation or activity. For example, interest of students in a chemical concept such as chemical bonding could be aroused, developed or sustained if and only if the students get involved in activities that will help them in learning and improving their performance on the concept or subject.

Appraising the tendencies to seek or avoid particular activities or objects constitutes the domain of interest measurement. In this study, efforts will be made to ascertain the interest of urban and rural secondary school students in Chemical Bonding. In Nigeria, rural life is uniform, homogenous and less complex than that of urban centres, with cultural diversity, which affect the interest of students. The urban centres are better favoured with respect to distribution of social amenities such as pipe borne water, electricity, healthcare facilities while the rural areas are less favoured. This is also true in the distribution of educational facilities and teachers. These prevailing conditions imply that ‘learning opportunities in Nigerian schools differ from school to school’ (Ariyo and Ugodulunwa, 2007:6). It would appear therefore that students in Nigerian urban schools have more educational opportunities than their counterparts in rural schools have. While some studies have shown positive influence, others have shown negative influence of school location on the interest of students and their learning outcome or achievement. Nwogu (2010) found that location was significant in learning aspects of mathematics that involve angles, with rural students exhibiting more learning difficulties than their urban counterparts do. Ahiaba and Igweonwu (2003) investigated the influence of school location on the performance of chemistry students in rural and urban schools at the SSC examination and found that chemistry students in urban schools performed better with superior grades, than their rural counterparts while failure rate was higher in the rural schools. Some studies (Bosede, 2010; Ezeh, 1998) showed no difference in academic achievement of students because of location. Agbir (2004) showed that rural students performed better on practical skills in chemistry than their urban counterparts did. The influence of location on students’ academic achievement remains controversial and inconclusive. This calls for further investigation.

Agbi (2006) assert that students’ interest in chemistry can be dampened by the use of inappropriate teaching method. This implies that the use of appropriate teaching method engenders students’ interest and achievement in chemistry. Chemistry teachers therefore should make teaching of difficult concepts such as chemical bonding interesting, real, lively and enjoyable by using innovative teaching strategies, such as the use of ICT.

Bosede (2010) showed that there is no difference in performance of students because of location. Location here is in terms of whether the place of study or school is cited in rural or urban community. Onah (2011) showed that urban students achieved more than the rural students did. No available literature from empirical studies explained if there is any differential performance because of gender and location in chemical bonding.

In evaluating learning outcome, the effect of gender and school location on learning and hence achievement in a teaching-learning process is often not taken into consideration. Curriculum designers and examination bodies do not make allowance for differences in school location and gender, hence students, irrespective of their gender and school location are subjected to the same teaching curriculum, teaching method and examination in a given subject. It is expected that teachers should be conscious of, and make allowances during classroom activities for differences in school location and gender. It is recognised that differences exist in the way individuals react to learning situations and materials. Davis (1977) noted that teaching and learning can take place anywhere (rural or urban), and at any time insofar as there is communication between the teacher and the learner. In this study, the chemical bonding Instructional Software package developed for it constituted the interactive multimedia that provided a platform for communication and interaction between the learning material and the learners, irrespective of their gender and location.

This present study is undertaken to investigate the numerous advantages, which literature attributed to computer-assisted instruction. It is undertaken because of the need to assist students in learning the concept of chemical bonding , which research (Peterson, Treagust and Garnett, 1986; Butts and Smith, 1987; Boo, 1998; Pereira and Pestana, 1991; Griffiths and Preston, 1992; and Nwahunanya, 2011) has identified as one that teachers and students find difficult in a teaching-learning situation.

Statement of the Problem

Chemical bonding is a concept found difficult by both rural and urban male and female students to learn. Students find it difficult to learn chemical bonding because of the abstract nature of the concept and the pedagogic approach adopted by teachers in presenting the concept to the students. Chemical bonding is regarded a difficult and abstract concept, because both the atoms, which take part in a chemical combination to form the bonds, the bonds themselves, and their process of formation are not concrete objects that can be seen with the naked eyes. They can only be conceptualised and imagined. Chemistry teachers in secondary schools find it difficult to teach chemical bonding, because they failed to devise necessary tools that will enable them help their students to visualise the bonding process.

A good understanding of chemical bonding is fundamental in students' progress in the study of and achievement in chemistry. Various traditional methods (lectures, discussion, guided discovery and expository) used in teaching chemistry, have contributed to students' learning difficulties and low achievement in chemistry (Ifeoma , 2005). This is because these traditional methods of teaching chemistry limit effective communication of chemical concepts to the students (Lasisi, 1998). The traditional methods have not been effective in communicating the concept of chemical bonding to students (Adeyegbe, 1998). The traditional methods have therefore failed to help students in the understanding and mastery of the concept, and may have interacted with other factors to contribute to low achievement of students in chemical bonding and chemistry generally. This is worrisome and compounded by disparity in school location (Ahiaba and Igweonwu, 2003; Nwogu, 2010) and gender (Adesoji and Babtunde, 2008). There is need to use other innovative teaching methods, as a way of improving students' achievement in chemistry generally and chemical bonding in particular. Curriculum planners (NERDC, 2009) look to and recommend the use of computer as an innovative strategy in teaching concepts in chemistry. The common trend in pedagogy since the turn of the 21^{st} century is the use of computer in delivering lessons on specific chemical concepts, using relevant instructional software package. For chemical bonding in chemistry, software packages tailored to the curriculum needs of the students are scarce. This makes imperative the development of appropriate software packages, which literature (Mbam, 2005 and Ekoko, 2006) revealed are scarcely available for Nigerian education system. Therefore, the problem of this study is embedded in the questions: How can a reliable, relevant instructional software package for the teaching and learning of chemical bonding in secondary schools be developed. What will be the effects of the instructional software package on the interest and achievement of students in chemical bonding?

The Purpose of the Study

The purpose of this study is to develop and validate a computer software package designed for the teaching of the concept of chemical bonding in secondary schools. Specifically, the purpose is to:

1. Design and construct a Chemical Bonding instructional Software Package (CBISP) that runs on computers.
2. Ascertain the effect of the use of CBISP on the students' interest in chemical bonding.

3. Ascertain the effect of CBISP on the mean achievement of students in chemical bonding.

4. Ascertain the interaction effect of teaching method and students' gender on their mean interest rating in chemical bonding .

5. Ascertain the interaction effect of teaching method and student location on their mean interest rating in chemical bonding.

6. Ascertain the interaction effect of teaching method and students' gender on their mean achievement in chemical bonding.

7. Ascertain the interaction effect of teaching method and students' location on their mean achievement in chemical bonding.

8. Ascertain the interaction effect of teaching method , students' location and gender on their mean achievement in chemical bonding.

9. Ascertain the interaction effect of teaching method, students' location and gender on their mean interest rating in chemical bonding.

10. Ascertain the interaction effect of teaching method, students' location and gender on their mean achievement in chemical bonding.

11. Ascertain the interaction effect of teaching method, students' location and gender on their mean interest rating in chemical bonding.

Significance of the study

The need to lay a solid foundation for the beginning students of chemistry by adopting an innovative teaching strategy that takes into consideration their interest in Information and Communication Technology (ICT), especially computer, inspired and informed this study. Since the advent of e-learning or the use of computer in learning, controversy has been raging among educators and designers of multimedia materials for human-computer interaction, as to whether computer-supported learning is better than the traditional learning environments, such as classroom or from a textbook. A school of thought asserts that studies and reports that promote e-learning very often are not based on research but rather on doctrine. In other words, much of what is said about the effectiveness of e-learning is theoretical. It is crucial to carry out a study and ascertain the effectiveness or otherwise of e-learning on both students' interest and achievement in learning. This is necessary because the 21st century society has come to embrace e-learning as a way forward in promoting learning. It is in this regard that the present study is very significant.

In addition, chemistry is at the centre of the various advancements the world has witnessed in recent years in science and technology, from life saving pharmaceuticals to computers and other information technologies. Therefore, the twenty-first century world is driven by science and technology in which chemistry plays a significant part. There is need, therefore, to rejuvenate and revitalise the learning experience of students in the subject. Innovative methods of teaching chemistry should be adopted, to make the study of the subject more interesting to today's young students, for whom the computer provides a multimedia learning system. A multimedia learning system is a technology-based learning system that combines the use of written words, images, sound, video, animation and interactive conversation to transmit information and enhance the teaching-learning process.

Chemical bonding is an abstract chemistry concept, which at a higher level of education is usually studied and understood better, using the tool of advanced mathematics. The use of mathematics in describing the concept of atomic bonding can be a distraction to young students, and prevents them from appreciating or ‘‘seeing’ the underlying concepts’. The CBISP that will be a major product of this study would be available as a resource material for classroom use to both teachers and students. It at will help to make the task involved in the teaching-learning process of chemical bonding easy. With the software, students could work individually and privately at their own pace, afford to make mistakes, learn from their mistakes without any fear of embarrassment. The subject is made alive as the students are enabled to focus on the science, and the students’ interest could be kindled, and sustained throughout the study of the concept. This way, teachers and students would no longer see chemical bonding as a difficult concept. The CBISP could therefore be for teachers a very important tool that would make them more effective and efficient in the delivery of the concept. This innovation could guarantee a sound foundation for students’ effective learning and achievement in the concept.

The CBISP could be a source of huge revenue to the Department of Science Education, if patented, produced in commercial quantity and sold for use in public and private schools. This is particularly significant now that universities are encouraged to look inwards and internally generate or source fund to meet their financial needs. Individuals or members of society with basic education, who may be interested in becoming scientifically literate, as a requirement to live effectively in the 21st century world, could buy and use the software, which will drill and entertain them while they learn and enjoy themselves, without resorting to reading books for the same lessons. Finally, the result of this study might go a long way in providing insight as to whether multimedia make a difference or not, and indeed on the actual benefits of e-learning in the education system. In particular, the result might throw more light on the effect of software method on students' interest and achievement on the difficult concept of chemical bonding.

Scope of the Study

The scope of this study is limited to the development, quality rating and testing of an Instructional Software package designed to facilitate the teaching and learning of chemical bonding, as documented in NERDC (2009) curriculum, to beginning students of chemistry at the senior secondary school class one (SS1). Senior secondary schools in Nsukka Education Zone of Enugu State, during the 2012/2013 academic year constituted the subject of this study.

Research Questions

The following questions guided the study:

1. What is the effect of the use of chemical Bonding Instructional Software package (CBISP) on secondary school students' achievement in chemical bonding?
2. What is the influence of students' gender on their achievement in chemical bonding?
3. What is the influence of location on the students' achievement in chemical bonding?
4. What is the effect of Chemical Bonding Instructional Software Package (CBISP) on students' interest in chemical bonding?
5. What is the influence of students' gender on their interest in chemical bonding?

6. What is the influence of students' school location on their interest in chemical bonding?

7. What is the interaction effect of gender and school location on students' mean achievement in chemical bonding?

8. What is the interaction effect of gender and method of teaching (CBISP and lecture) on students' mean achievement in chemical bonding?

9. What is the interaction effect of location and method of teaching (CBISP and lecture) on students' achievement in chemical bonding?

10. What is the interaction effect of gender and school location on students' mean interest rating in chemical bonding?

11. What is the interaction effect of gender and teaching method on students' interest in chemical bonding?

12. What is the interaction effect of school location and teaching methods on students' interest in chemical bonding?

Hypotheses

The following null hypotheses that guided the study were tested at 0.05 level of significance ($P < 0.05$):

$Ho_{1:}$ There is no significant difference between the mean achievement scores of students taught chemical bonding using CBISP and those taught using lecture method.

Ho_2 Students' gender does not significantly influence their mean achievement in chemical bonding.

Ho_3 School location does not significantly influence students' mean achievement in chemical bonding.

Ho_4 There is no significant difference in the students' interest in chemical bonding between those taught chemical bonding using CBISP and those taught using lecture method.

Ho_5 The influence of gender on students' mean interest rating in chemical bonding is not significant.

Ho_6 The influence of school location on students' mean interest rating in chemical bonding is not significant.

Ho_7 The interaction effect of gender and teaching method on students' mean achievement in chemical bonding is not statistically significant.

Ho_8 The interaction effect of gender and teaching method on students' mean achievement in chemical bonding is not significant.

Ho_9 The interaction effect of location and method of teaching on students' mean achievement in chemical bonding is not significant.

Ho_{10} The interaction effect of gender and location on students' mean interest rating in chemical bonding is not significant.

Ho_{11} The interaction effect of gender and method of teaching on students' mean interest rating in chemical bonding is not significant.

Ho_{12} The interaction effect of method of teaching and location on students' mean interest rating in chemical bonding is not significant.

Ho_{13} The interaction effect of teaching method, students' location and gender on their mean achievement in chemical bonding is not significant.

Ho_{14} The interaction effect of teaching method, students' location and gender on their mean interest rating in chemical bonding is not significant. **CHAPTER TWO**

LITERATURE REVIEW

In this chapter, studies that have bearing on the present work are reviewed and organised in the following order:

Å Relevance of the Conceptual Framework

Å The Atom: Its Nature, Structure and Behaviour in Chemical Bonding

Å Concept of Chemical Bonding

Å Technical Terms used in Discussing Chemical Bonding

Å Models of Chemical Bond

Å Concept of e-Learning

Å Educational Software Package

Theoretical Framework

Å Teaching and Learning

Å Evaluation of Teaching and Learning in Chemistry Education

Å Adolescent Learners

Å Theories of Instruction and Learning

Å Bruner's and Gagné's Theories of Instruction

Å Theories of Learning

Å Gagné's, Bruner's and Ausubel's Theories of Learning

Å E- Learning: Use of Computer in Education

Å Theories of Software Development

Models of Software Development

- Waterfall Model of Software Development

Review of Empirical Studies

Å Gender, School Location, Interest and Achievement in Chemistry

Å Studies on Gender-related Differences in Interest and Achievement in Chemistry

Å Effect of multimedia Instruction on Students' Learning Outcome

Å Effects of Multimedia Technologies on Nigerian Students' classroom learning

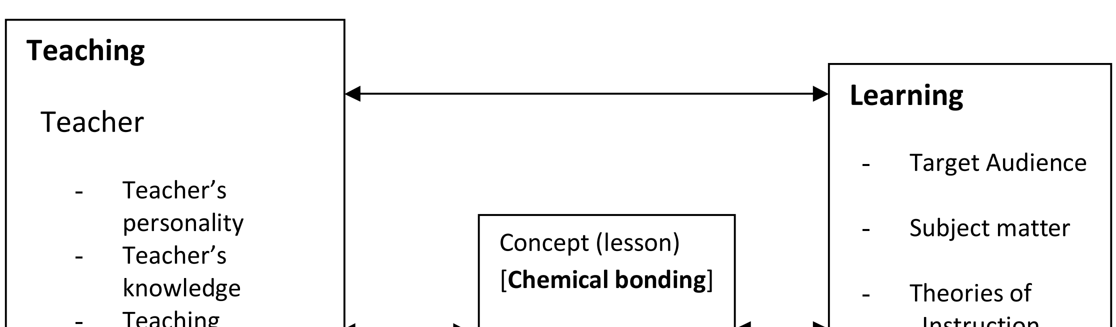
Å Effect of Multimedia Instruction on Students' Academic Interest

Summary of Literature Review

Conceptual Framework

In this section, a brief description of the main variables in this study is presented in a graphic form; and later explained, in an attempt to illustrate the interaction of the concepts and their relationship with the problem of the study.

Since in a teaching and learning or simply teaching-learning process, the student is expected to produce an 'outcome' or achievement, both the student and achievement (outcome) also form part of the conceptual framework (Fig.1).



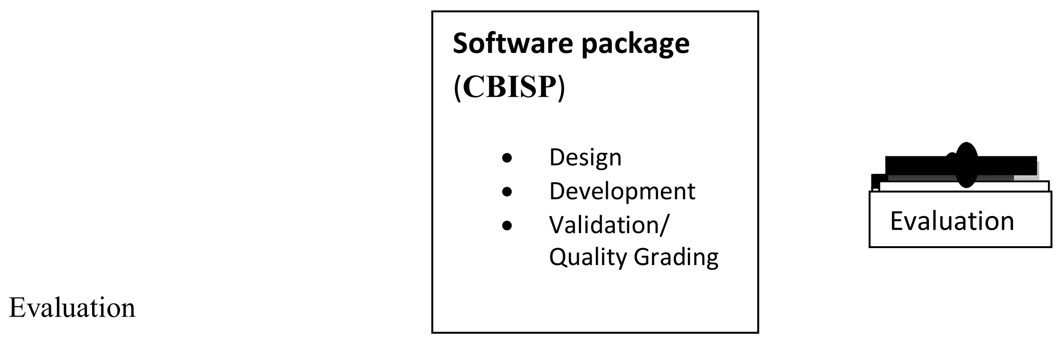


Fig.1 Conceptual Framework for the Development of Chemical Bonding Instructional Software Package (CBISP) for the Teaching Of Chemical Bonding

In the diagram, the principal concept variables are achievement, interest, location, gender and teaching method. The arrows indicate the interaction between the various concepts, which define the software users' need.

Precisely, the conceptual framework depicts the interaction of the aforementioned concepts, especially concept of chemical bonding (to be imparted to the students) and educational software, with teaching–learning process in which the students, using the computer in learning, control the learning in order to meet the instructional objectives (desired learning outcome or achievement).

It is necessary to understand from the outset, the relevance of this conceptual framework to the development and quality grading of the educational software package to be used in this study. For this reason, the following explanation of the relationship between the various concepts, which together form the conceptual framework, is imperative.

Relevance of the conceptual framework to the development of the educational software package

The interaction of the various concepts define the educational software users' needs. These needs are identified in the design plan for the development of the educational software package. The input into the educational software package such as the visuals, e.g. the shape of the atom, its spinning, colours, the bonding process of the atom and other information are identified with the help of the conceptual framework. These are tailored to the users needs based on the recommendation of the curriculum content that is being addressed or focussed on. The satisfaction of these needs is the aim of the educational software package. The conceptual framework is related to this study, because it provides a guide to the researcher with respect to the needs of the intended users of the educational software package, how to go about providing these needs and above all the kind of software developmental model to be adopted and or adapted in developing the software package. The conceptual framework also provides the researcher an idea of the input into, and how to construct an instrument for the quality grading of the software package.

The various concepts are themselves influenced or affected by certain factors. Under each of these concepts, a number of probable factors are listed, whose interaction define the uniqueness of the concepts. The intended primary users of the software are the teacher and the students whose needs are determined by those factors listed under them.

The Chemical Bonding Instructional Software Package (CIESP) being developed for the teaching of chemical bonding aims at meeting the needs of these primary users in a teaching-learning process of the concept. Perhaps it is apt at this point to explain some of the concepts in the conceptual framework.

The Atom: Its Nature, Structure and Behaviour in Chemical Bonding

An atom is the smallest particle of an element that shows the chemical behaviour of that element (Bettelheim and March, 1991). It is the almost infinitesimally small building block of matter. Matter is the physical material of the universe; it is anything that has mass and occupies space (Brown, Lemay, Bursten and Murphy, 2009). Matter exists in three states: solid, liquid and gas (Okeke and Ndupu, 2004; Okeke, Okeke and Akande, 2009). The paper on which this research is presented, our body, the clothes we are wearing, the water we drink and the air we are breathing are all samples of matter.

Countless experiments have shown that the tremendous variety of matter in the world is due to combinations of only about 100 very basic or elementary substances called elements (Brown et al, 2009). An element is a pure substance that cannot be broken down into simpler substances by chemical reactions, that is, by ordinary chemical means, such as the application of heat, light or electric energy (Bettelheim and March, 1991; Brown, et al, 2009).

Our current understanding of the nature, structure and behaviour of the atom is based on the studies carried out by earlier scientists in an attempt to have a physical picture of the atom. These earlier scientists include J.J. Thompson (1856-1940), Enerst Rutherford (1871 – 1937), James Chadwick (1891 – 1972), Niels Bohr (1885 – 1962), Albert Einstein (1892 – 1955), Max Plank (1858 – 1947), Louis de Broglie (1892 – 1987), Werner Heisenberg (1901 -1976), Erwin Schrodinger (188–1961), Wolfgang Pauli (1900–1958), Friedrich Hund (1896-1997), Otto Stern(1888 - 1969) and Walter Gerlach (1889 - 1979).

The studies in reference include Blackbody radiation, Photoelectric effect and emission , Line spectra, Wave behaviour of matter, Uncertainty principle, and Quantum mechanics or Wave mechanics. Quantum mechanics is a set of principles describing physical reality at the atomic level of matter (molecules and atoms) and the subatomic (electrons, protons and even smaller particles). These description include the simultaneous wave-like and particle-like behaviour of both matter and radiation energy. In the quantum mechanics of a subatomic particle, one can never specify its state, such as its simultaneous location and velocity, with complete certainty. This is called the Heisenberg Uncertainty Principle.These studies are well documented in literature, for example, Brown, Le May, Bursten and Murphy (2009); Engel and Reid, (2006); Huheey, Keiter, and Keiter, (1993); Sharpe, (1992); Bettleheim and March (1991); Schubert, and Veguilla-Berdecia (1973).

The atom is composed, in part, of electrically charged subatomic particles some with a positive (+) charge and, some with a negative (-) charge. Three of these subatomic particles, the electron, neutron and proton are of special interest to chemists, because they have bearing on chemical behaviour of the atom. The charge of the electron is -1 and that of the proton is +1. Neutrons are uncharged and are therefore electrically neutral. Every atom has an equal number of electrons and protons, so atoms have no net electrical charge. Protons and neutrons reside together in the nucleus of the atom. The vast majority of an atom's volume is the space in which the electrons reside. The electrons are attracted to the protons in the nucleus by the electrostatic force that exists between particles of opposite electrical charge (Brown, et al 2009).

The mass of the atom is extremely small, and is measured in atomic mass unit, or amu. One amu equals 1.66054 x 10^{-24}g. The masses of the proton and neutron are very nearly equal, and both are much greater than that of the electron; a proton has a mass of 1.0073 amu, neutron 1.0087 amu, and an electron 5.486 x10^{-4} amu. Because it would take 1836 electrons to equal the mass of 1 proton, the nucleus contains most of the mass of an atom. Table 2 summarises the charges, and masses of the subatomic particles.

Table 2 Charges and masses of subatomic particles

Particle	**Charge**	**Mass** (Units)
Proton	Positive (+)	1.0073
Neutron	None (Neutral)	1.0087
Electron	Negative (-)	5.486 x 10^{-4}

Models of the Atom

Models may be conceptual, mathematical or numerical depending on whether the set of concepts are expressed qualitatively or a set of equations that describes how things work or, a computer simulations which allows models to be developed of very complex systems, respectively (Malgwi, 2006). In this research, two models of the atom - the Bohr and the quantum mechanical models are used. In the Bohr model of the atom, the electrons move round the nucleus in orbits, like planets round the sun.

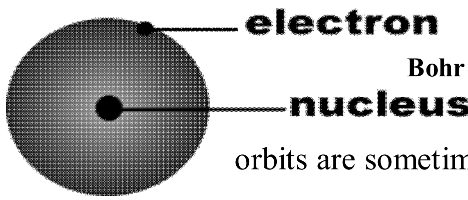


Fig. 2. Bohr model of the atom

The orbits are sometimes denoted by the letters K, L, M, N… counting outwards from the nucleus, and they are numbered 1, 2, 3, 4. This number is called the *principal quantum number*, which is given the symbol *n*. It is therefore possible to define which circular orbit is under consideration by specifying the principal quantum number.

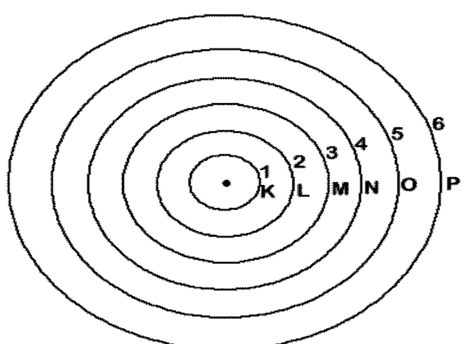


Fig. 3. The orbits that denote the *principal quantum* number represented by the letters K, L, M, N… numbered 1, 2, 3, 4..,

In the quantum mechanical model of the atom, the word orbital is used in place of orbit (Bohr model), to describe a specific distribution of electron density in space, as given by the orbital's probability density. The other quantum numbers are the angular momentum quantum number, *l*, which can have integral values from 0 to (*n*-1) for each value of *n*; the magnetic quantum, *m*, which can have integral values between -*l* and *l*, including zero. The angular momentum quantum number defines the shape of the orbital, while the magnetic quantum number describes the orientation of the orbital in space.

The collection of orbitals with the same value of *n* is called an *electron shell*. All the orbitals that have *n=3*, for example, are said to be in the third shell. Further, the set of orbitals that have the same *n* and *l* values are called a ***subshell***.

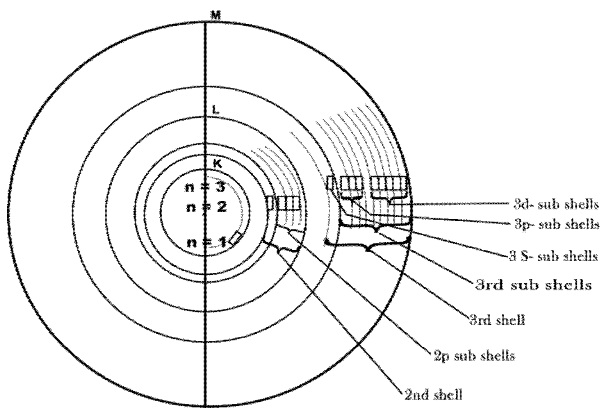


Fig 4 Electron shells and subshells in an atom

Each orbital in the atom has a characteristic energy and shape. For example, the lowest-energy orbital in the hydrogen atom has an energy of -2.18×10^{-18} J and the shape illustrated below.

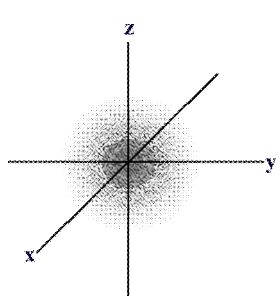


Fig 5 Electron-density distribution in the hydrogen atom

An orbital (quantum mechanical model) is not the same as an orbit. The quantum mechanical model does not refer to orbits, because the motion of the electron in an atom cannot be precisely measured or tracked (Heisenberg Uncertainty Principle).

The Bohr model of the atom introduced a single quantum number *n*, to describe an orbit. The quantum mechanism model uses three quantum numbers, *n*, *l*, and *m*, which result naturally from the mathematics used, to describe an orbital.

There are about 118 known elements; and all are built up from these three fundamental particles - proton, neutron and electron in a simple way. The first simplest element, hydrogen, has a nucleus containing one proton and therefore has one positive charge, which is balanced by one negatively charged orbital electron.

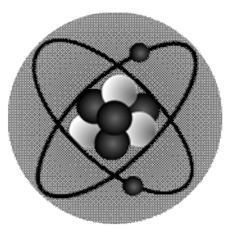


Fig 6 Structure of an atom

The electrons speed around the nucleus so fast that they are not actually in one location, but rather smeared across a region of the electron cloud. Electrons have a high velocity, and the larger the nucleus they are orbiting the faster they move. In a hydrogen atom, the electron has been calculated to be orbiting at a speed of approximately 2,420,000m/s (Argonne National Laboratory, 2011).

Electron could move from one orbital (energy level) to the other. The movement of an electron from one orbital to another gives a single sharp line in the spectrum, corresponding precisely to the energy difference between the initial and final orbitals. Within the atom, the electrons are arranged according to their various energy levels in the *s,p,d* or *f* suborbitals or subshells, corresponding to the value of l. For example, the orbitals that have $n = 3$ and $l = 2$ are called 3*d* orbitals and are in the 3*d* subshell. The letters *s, p, d,* and *f* come from the words sharp, principal, diffuse and fundamental which were used to describe certain features of spectra before quantum mechanics was developed (Brown et al, 2009). Table 3 is a summary of possible values of the n through $n = 4$. It shows the relationship among values of *n, 1*, and *m,* through $n = 4$.

Table 3 Energy levels in the atom showing relationship among values of *n, 1*, and *m,* through $n = 4$

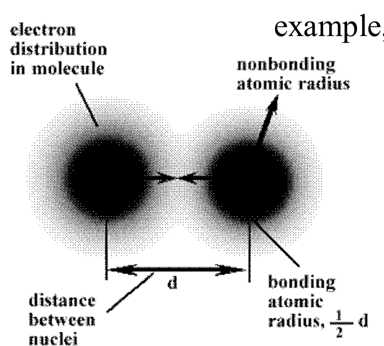
n	Possible values of *l*	Subshell Designation	Possible Values of *ml*	Number of Orbitals in Subshell	Total Number of orbitals Shell

1	0	1*s*	0	1	1
2	0	2*s*	0	1	
	1	2*p*	-1 , 0, 1	3	4
3	0	3*s*	0,	1	
	1	3*p*	-1, 0, 1	3	
	2	3*d*	- 2, -1, 0, 1, 2	5	9
4	0	4*s*	0	1	
	1	4*p*	-1, 0, 1	3	
	2	4*d*	- 2, -1, 0, 1, 2	5	
	3	4*f*	-3, -2,-1, 0, 1, 2, 3	7	16

Shape and size of Atoms

Very often atoms are presented as a sphere. This is because closed-shell atoms are spherically symmetric (Engel and Reid, 2006). However, atoms and ions (atoms that have gained or lost electrons) do not have sharply defined boundaries at which the electron distribution becomes zero. The size of an atom is therefore at best nebulous because an atom can have no well-defined boundary similar to that of a billiard ball. It is impossible to set up a single set of values called 'atomic radii' applicable under all conditions. It is necessary to define the conditions under which the atom exists and the method of measurement (Huheey, et al, 1993).

Atomic size is defined in several ways, based on the distances between atoms in various situations. For example, *bonding atomic radius* and



nonbonding atomic radius are used to describe the size of the atom. The nonbonding atomic radius of an atom is the closest distance separating the nuclei of atoms when the atoms merely collide with each other. The bonding radius is used to describe the distance separating the nuclei when the atoms are chemically bonded to each other. When two atoms collide with each other in the course of motions, they ricochet apart - somewhat like billiard balls. This movement happens because the electron clouds of the colliding atoms cannot penetrate each other to any significant extent (Brown et al, 2009).

Fig 7 Collision of atoms

Most times the size of the atom refers to the atomic radius as defined above. The knowledge of atomic radii is necessary in estimating the bond length between different elements in molecules. For example, the Cl-Cl bond length in Cl_2 is 1.99 Å, so the radius of 0.99 Å is assigned to Cl. In the tetrachloromethane compound (CCl_4), the measured length of C-Cl bond is 1.77 Å, very close to the sum (0.77 + 0.99 Å) of the atomic radii of C and Cl.

This review of the nature of the atom helped the reseacher in designing the shape and size of the models of the atoms used in this study. This was done in an attempt to aid the students in visualising the atom and its involvement in chemical bonding for which this software was being developed.

The Periodic Table of Elements

When elements are arranged in order of increasing atomic number, their chemical and physical properties show a repeating, or periodic pattern. The atomic number of an element is the number of protons in the atomic nucleus. The periodic table therefore is the arrangement of elements in order of increasing atomic number, with elements having similar properties placed in vertical columns. It is the most significant tool that chemists use for organising and remembering chemical facts (Brown et al, 2009). A typical periodic table, as recommended by the International Union of Pure and Applied Chemistry (IUPAC) is shown in Table.4. Beginning students of chemistry very often encounter the first 90 elements in the Periodic Table in the course of their studies. There are about 118 known elements (Engel and Reid, 2006).

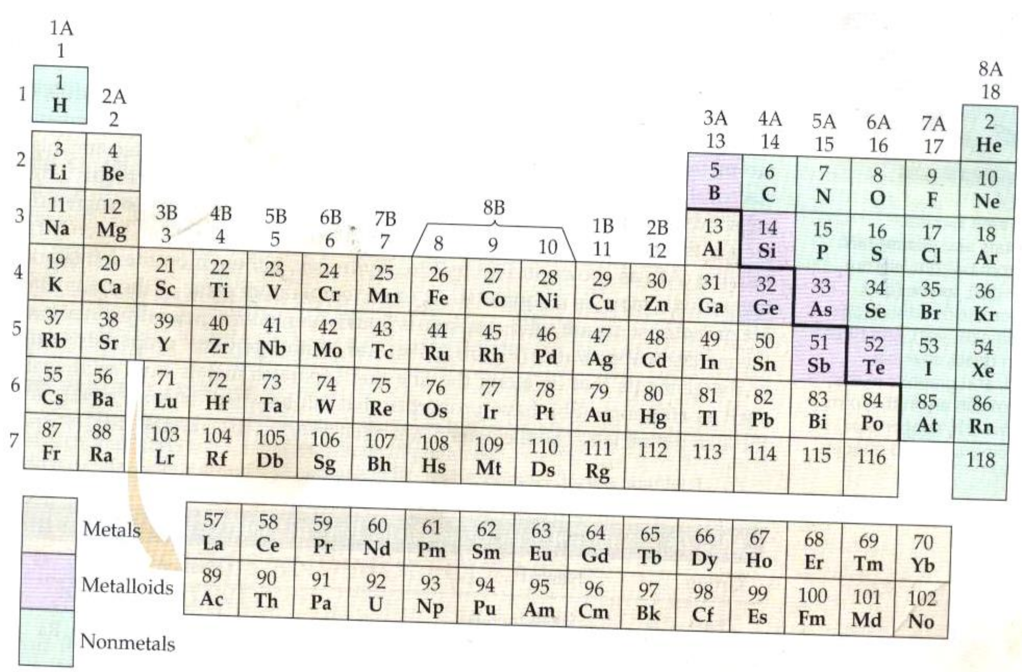


Table.4: The periodic table of elements

The horizontal rows of the periodic table are called periods while the vertical columns are called groups. Except for hydrogen, all the elements on the left side and the middle of the periodic table are metallic elements or metals. Most of the elements are metallic; they all share characteristic properties, such as lustre, and high electrical and heat conductivity. All metals, with the exception of mercury (Hg), are solid at room temperature. The metals are separated from non-metallic elements, or non-metals, by a diagonal step-like line that runs from boron (B) to astatine (At).

Hydrogen, although on the left side of the periodic table, is a non-metal. At room temperature, some of the non-metals are gaseous, some are solid, and one (bromine, Br) is liquid. Non-metals generally differ from the metals in appearance, and in other physical properties. Many of the elements that lie along the line that separates metals from non-metals, such as antimony (Sb), have properties that fall between those of metals and those of non-metals. These are called *metalloids* (Brown et al, 2009).

Value of the Periodic Table

The periodic table is useful in systematic classification of elements according to their properties. Examples of such properties include the atomic size, ionisation energy, and electron affinity, which occur at regular intervals. This information is valuable in determining the type of chemical bond and hence, compounds, which certain elements form. The periodic table makes the study of chemistry easier.

The significance of this review lies in the fact that in developing the software for the teaching of chemical bonding to adolescent students, which is the concern of this research, cognisance must be taken of the fact that each child comes with unique strengths, challenges, and needs. The software should therefore help the students to think creatively, identify and solve complex and meaningful problems, know their passions, strengths, and challenges; communicate and work well with others, and manifest other attributes of educated individuals. In communicating with others, the student is expected to use the language of the subject. In this present study, an educational software package that illustrates how bonds are formed will be developed and tested to determine its effects on students' interest and achievement in chemical bonding process.

Concept of Chemical Bonding

Chemical bonding is the process of formation of chemical bonds. Chemical bonds are powerful attractions that hold atoms together. An atom is the smallest particle of an element that shows the chemical behaviour of the element (Bettleheim and March, 1991). The atom, its structure, the process of bond formation and the bonds formed are not concrete or physical in nature. They are neither tangible, nor visible; they can only be conceptualised and discussed. Conceptualisation of abstract, intangible and invisible things such as atoms and chemical bonds or a process such as chemical bonding makes a lot of demand on the intellect. It could bring about mental exertion, especially if there is no deliberate effort made to use concrete objects to aid students to conceptualise the abstract concept taught in the lesson delivered, using lecture method. This perhaps explains why students find it difficult to learn chemical bonding.

A chemical bond is formed between two atoms if the energy of the molecule is lower than the energy of the separated atoms (Engel and Reid, 2006). The process of bond formation and the bonds formed are not physical in nature and therefore are conceptualised and discussed using mathematical models. The simplest of such models include the valence bond (VB) and molecular orbital (MO) 'used to understand and predict the shape of small molecules' (Engel and Reid, 2006). Understanding chemical bonding is fundamental to the study of chemistry. It helps to explain why and how chemical reactions occur and to predict the product and properties of such products of the chemical reaction. It helps to explain, for instance, the existence of chemical species. 'A chemical species is any type of particle: atom, ion, or molecule' (Bettelheim and March, 1991).

Technical Terms used in Discussing Chemical Bonding

Chemistry has its own unique technical language, which if properly used will enable the individual to express his ideas and communicate effectively with others. In discussing chemical bonding, certain technical terms are used. These include ionisation, electron affinity, electronegativity, bond strength, ionic bond, covalent bond, bond axis, bond angle and bond length. A good understanding of these terms will help the students and teacher to communicate effectively with one another in the teaching-learning process. These terms are therefore explained below.

Ionisation and Electron Affinity

Some atoms tend to give up electrons and become positive ions in a process called **ionisation** while others tend to gain electrons or have electron affinity. In all these tendencies, bonds are formed.

Electronegativity and Bond Character

The relative tendency of an atom to attract electrons to itself when bound with another atom is known as electronegativity. Electrons are transferred between atoms when the difference in electronegativity between the atoms is quite high. If the electronegativity difference between two reacting atoms is small, we might expect a sharing of electron as in the case between hydrogen and halogens (Brown et al, 2009) (see Table 5).

Table 5 Strength of bonds between hydrogen and halogens (group 7 elements of the periodic table).

Bond	Bond Strength (KJ/mol)	Electronegativity Difference
H-F	569	1.80
H-CL	432	0.80
H-Br	366	0.62
H-l	299	0.28

Covalent Bonds

If two elements combine by sharing electrons, they are said to form a covalent bond. Atoms with the same or nearly the same electronegativities tend to react by sharing electrons. The shared pair or pairs of electrons constitute a covalent bond. Covalent compounds typically have low melting points, do not conduct electricity, and are brittle.

Ionic Bond

When two atoms combine by transfer of electrons, ions are produced. The opposite charges of the ions hold them together. When two atoms combine by electron transfer, they are said to form an ionic bond.

Bond Strength

The stability of a molecule when formed is related to the strength of the bonds it contains. The strength of a bond between two atoms is the energy required to break that bond.

Bond Axis, Bond Angle and Bond Length

When two or more atoms bond covalently, the resulting particle is called a **molecule**. The line joining the nuclei of two bonded atoms in a molecule is called the **bond axis**. If one atom is bonded to each of two other atoms, the angle between the two bond axes is called the **bond angle**. The distance between the nuclei along the bond axis is called the **bond length**. The length is not really fixed, because the bond acts much as if it were a stiff spring. The bonds vibrate as though they were alternately stretching and shrinking. These movements cause the bond angles and length to vary. The measured bond lengths and bond angles are average values. They may be regarded as the values for a molecule completely at rest. However, in accordance with kinetic-molecular theory of matter, molecules are in continuous motion, molecular motion never entirely ceases (Huheey et al. 1993; Engel & Reid, 2006).

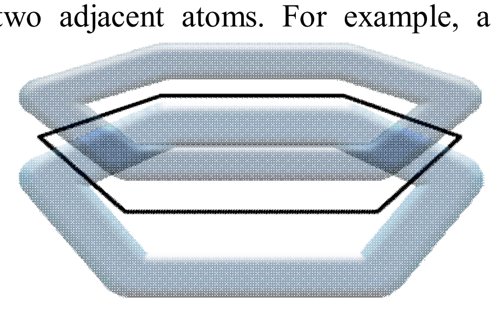
The knowledge about the structure of molecules comes from infrared spectroscopy, a branch of study in chemistry in which using an instrument, the infrared spectrophotometer, a molecular compound can be identified by the infrared radiation it absorbs or transmits. Each molecular compound has its own infrared spectrum, which is different from that of any other compound. The infrared (IR) spectrum indicates energy changes in the bonding between the particles of the molecules.

Models of chemical bond

Two distinctly different models, namely the valence bond (VB) model and the molecular orbital (MO) model, describe the chemical bond. The valence bond model is a localised description of the chemical bond in which each bond in a molecule is associated with an electron pair. The pair is made up of one electron from each of the two atoms involved in the bond and has a net spin of zero (Huheey et al, 1993).

The molecular orbital model is a delocalised description of chemical bonding. Molecular orbitals (MOs) that extend over the whole molecule are constructed by making linear combinations of Atomic Orbitals (AOs) (LCAOs). For this reason, one refers to the LCAOs-MO models. Electrons are placed into these MOs just as they are placed in the AOs of many-electron atoms.

The valence bond model reinforces the idea that chemical bonds are localised between two adjacent atoms. For example, a localised picture is more useful than a



delocalised model in visualising C-Cl bond cleavage in ethyl chloride. On the other hand, the MO theory initially assumes that electrons are delocalised over the entire molecule. However, calculations show that some MOs are largely localised between two adjacent atoms (Engel and Reid, 2006). Therefore, the MO model is capable of describing both localised and delocalised bond. The delocalised picture of a chemical bonding is useful when describing bonding in a compound such as benzene (C_6H_6) or a metal such as copper.

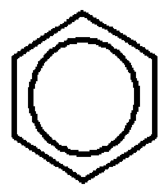


Fig 8 Delocalised bonding in benzene

The π electrons in benzene and the conduction elections in a metal are truly delocalised. A metal such as copper is made up of a lattice of rigid spheres (positive ions), embedded in a 'sea' of free valency electrons (Fig 8). The electrons are held on to the metal by electrostatic attraction to the cations, and they are evenly distributed throughout the structure. The electrons are in motion, however, and no individual electron is confined to a particular metal ion. They are free and could move in the interstices.

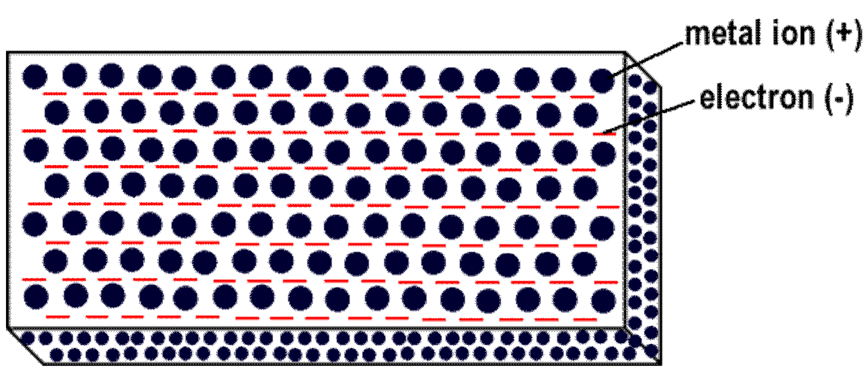


Fig 9 Delocalised bonding in metal

This explains the free movement of electrons, and cohesion results from electrostatic attraction between the positive ions and electrons clouds. It also explains why an increased number of valency electrons results in increased cohesion energy (Brown et al, 2009; Lee, 1979). A localised picture (VB model) of chemical bonding is unable to describe the energy lowering that arises in an aromatic system or in a metal. A localised (MO) model must be used instead (Engel and Reid, 2006). These examples show that both the VB and MO models are useful in understanding chemical bonding, and molecular structure.

A thorough understanding of the two theories by teachers is very important, as both constitute useful tools that will enable teachers to effectively guide the students in having a clear picture of chemical bonding. None of the two theories can explain everything about chemical bonding to the exclusion of the other. Huheey et al (1993) observed that given a specific situation or question, one theory may prove distinctly superior in insight, ease of calculation, or simplicity of results; but a different question may reverse the picture completely.

The Octet rule and Lewis structure

Atoms in reactions gain, lose, or share electrons to achieve the same number of electrons as the noble gas closest to them in the periodic table. The noble gases have very stable electron arrangements, as evidenced by their high ionisation energies, low affinity for additional electrons, and general lack of chemical reactivity. Because all noble gases (except He) have eight valence electrons, many atoms undergoing reactions also end up with eight valence electrons. This observation is the basis for the octet rule: Atoms tend to gain, lose, or share electrons until eight valance electrons surround them.

The electrons involved in chemical bonding are the valance electrons which for most atoms, are those residing in the outermost occupied shell of an atom. The Lewis symbol is the simple way of showing the valence electrons in an atom and tracking them in the course of bond formation, using what are known as Lewis electron-dot symbols, or merely Lewis symbol. The Lewis symbol for an element consists of the chemical symbol for the element plus a dot for each valance electron (Brown et al, 2009). For example, chlorine has the electron configuration [Ne]$3s^2 3p^5$ while its Lewis symbol is

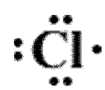
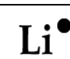
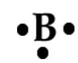
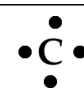
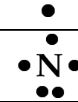
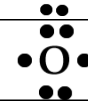
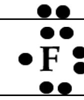
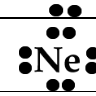
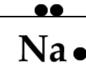
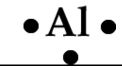
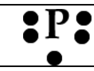
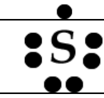
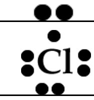
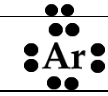


Fig 10 Lewis structure for chlorine

Table 6 Electron configurations and Lewis symbols for the representative elements

Element	**Electron configuration**	**Lewis**
Li	**(He) $2s^1$**	
Be	**(He) $2s^2$**	
B	**(He) $2s^2 2p^1$**	
C	**(He) $2s^2 2p^2$**	
N	**(He) $2s^2 2p^3$**	
O	**(He) $2s^2 2p^4$**	
F	**(He) $2s^2 2p^5$**	
Ne	**(He) $2s^2 2p^6$**	
Na	**(Ne) $3s^1$**	

Mg	**(Ne) 3s^2**	
Al	**(Ne) 3s^{2}3p^1**	
Si	**(Ne) 3s^{2}3p^2**	
P	**(Ne) 3s^{2}3p^3**	
S	**(Ne) 3s^{2}3p^4**	
Cl	**(Ne) 3s^{2}3p^5**	
Ar	**(Ne) 3s^{2}3p^6**	
K	**(Ar) 4s^1**	
Ca	**(Ar) 4s^2**	

An octet of electrons consists of full s and p sub shells in an atom. In terms of Lewis symbols, an octet can be thought of as four pairs of valence electrons arranged around the atom, e.g. as in the Lewis symbol for Ne in Table 6. The electron configurations and Lewis symbols for the representative elements of the second and third rows of the periodic table are shown in Table 6.

Valence Shell Electron Pair Repulsion (VSEPR) Theory

The VSEPR theory is based on Lewis structures. The theory states that the electron pairs in the outer shell of an atom try to get as far away from each other as possible. This is obvious because they are all negatively charged, and like charges repel. In applying this theory, what is needed is to draw the Lewis structure and look for an atom known as the central atom, connected to two or more other atoms; thereafter, the number of electron pairs in the outer shell of the central atom is counted, while observing the following rules:

(i) It does not matter whether an electron pair is unshared or bonded to another atom. It counts just the same.

(ii) For the purposes of VSEPR, a double or triple bond counts as one pair because it occupies one region of space.

From the VSEPR the shapes of molecules resulting from bonding of atoms can be determined. In deed, the number of electron pairs in the outer shell of the central atom tells us the shape of the molecule. With two pairs, the shape is linear (Brown et al, 2009).

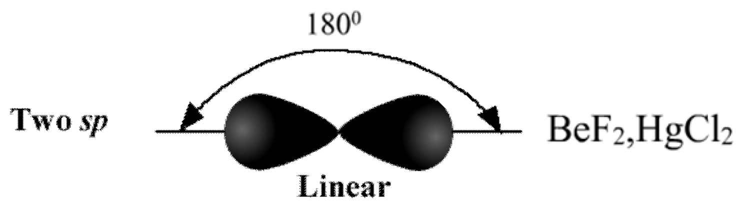


Fig 11 Shape of a molecule with two electron pairs

In CO_2 the central atom, carbon has two VSEPR pairs. In C_2H_2 there are two central atoms, each with two VSEPR pairs. The VSEPR theory predicts that both should be linear and both are.

The boron atom in boron trifluoride, BF_3, according to Lewis structure has only six electrons in the outer shell. There are three electron pairs around the B atom; VSEPR predicts that the molecule should be triangular, with all four atoms in a plane and F-B-F angles of 120°, which is the case.

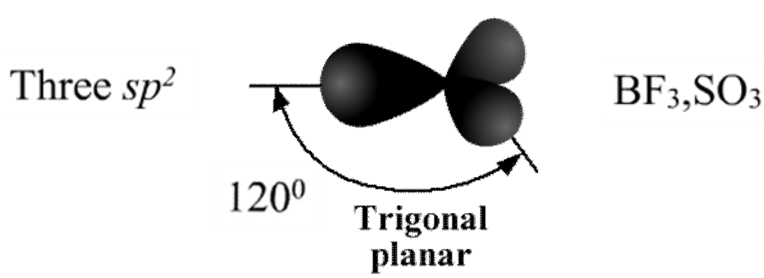


Fig 12 Shape of a molecule with three electron pairs, e.g. boron trifluoride, BF_3; sulphur tioxide, SO_3

Another example is ethylene, C_2H_2.

For four electron pair as in CH_4 and Cl_4, VSEPR predict that all carbon atoms with four single bonds have tetrahedral shapes; and the angle between any two groups in this geometry is 109.5° (Brown et al, 2009).

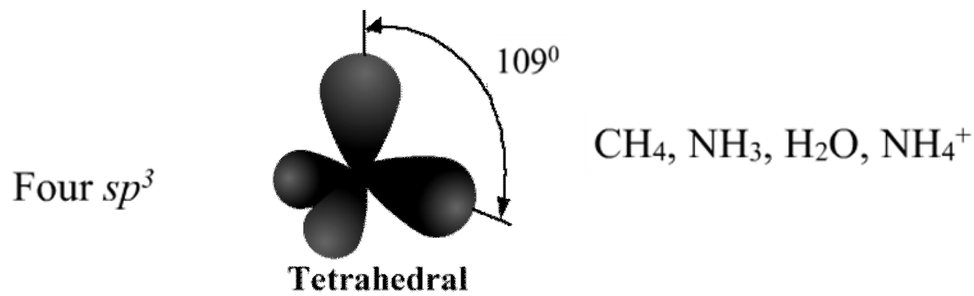


Fig 13 Tetrahedral shape of four electron pair molecules, e. g. CH_4,CH_3, H_2O, NH_4^+ and CCl_4

Hybridisation Theory

The concept of Lewis structures and the VSEPR model give an insight into chemical bonding and make it possible to predict the shapes of molecules. However, these models are not enough to predict some other important properties of covalent bonds, especially in organic molecules. For example, the Lewis model cannot explain why a carbon-carbon double bond is more reactive than a four carbon-carbon single bonds, with four hydrogen in methane (CH_4) when its valence electrons are in different atomic orbitals ($2s^22p^2$).

The theory of hybridisation was developed by chemists to explain these other properties. In hybridisation theory, it is recognised that an *s* orbital is spherical, and a *p* orbital is dumbbell-shaped. In the tetrahedral-bonded carbon atom, such as in methane (CH_4), which is made up of four equivalent C-H bonds, and tetrachloromethane (CCl_4), which is made up of four equivalent C-Cl bonds (Lee,1979; Schubert & Veguilla-Berdecia, 1973), the Lewis structure is:

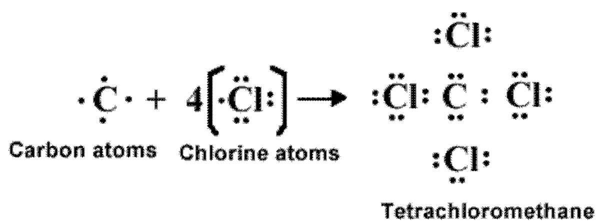


Fig 14 Lewis Structure for CCl_4

All the four orbitals have a character, which is intermediate between that of one *s* and three *p* orbitals: they are called sp^3 hybrid orbitals. A sp^3 orbital is neither spherical nor dumbbell–shaped, but has a mixture of the two shapes. A sp^3 hybrid has the shape shown in Fig 15.

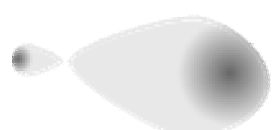
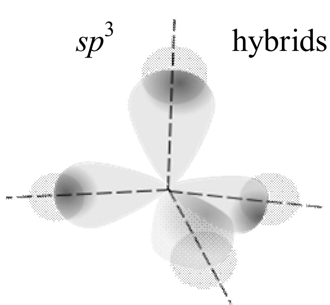


Fig 15 Shape of a sp^3 hybrid orbital

It is the larger lobe, which is involved in orbital overlap, and often for sake of simplicity, the small one is omitted in diagrams of molecules. (Arene and Kitwood, 1982). The four covalent bonds are formed by overlap between the atomic orbitals of the carbon atom and the atomic orbitals (1*s*) of four hydrogen atoms. However, the valence electrons in a carbon atom do not occupy four orbitals. Two electrons are in an *s* orbital and the other two are in *p* orbitals that are 90^o to each other (Bettelheim and March, 1991)

When sp^3 hybrids form bonds, there is greater orbital overlap than there



would be if the *s* and *p* orbitals were used separately, therefore the bonds are stronger. The bond formed is known as a sigma (σ) bond. The four equivalent sp^3 orbital (Fig 16), get as far away from each other as they can. As the VSEPR theory predicted, this means that the bond angles will be 109.5° (Engel and Reid, 2006; Brown et al, 2009)

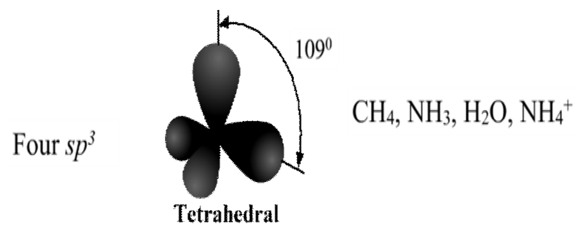


Fig 16 Four equivalent sp^3 orbital

Types of Chemical Bonding

There are three main types of chemical bonding: ionic bonding, or electrovalency, covalency and metallic bonding. In this present work, these three kinds of bonding are classified into **strong** and **weak** bonding as recommended by NERDC chemistry curriculum used in Nigerian Senior Secondary Schools.

Ionic Bonding

Ionic bonding is the chemical reaction in which bonds are formed between atoms of very active metallic elements and those of very active nonmetals. For ionic bonding to occur, two conditions are significant, the ionisation energy to form the cation, and the electron affinity to form anion, must be energetically favourable, which means that these two reactions must not cost two much energy. Therefore, the necessary conditions for ionic bonding are:

i) the atoms of one element must be able to lose one or two electrons without undue energy input and

ii) the atoms of the other element must be able to accept one or two electrons without undue energy inputs. This restricts ionic bonding to compounds between the most active metals: Groups 1,2, part of 3 and some lower oxidations states of the transition metals (forming cations), and the most active non-metals: Groups (17), 16 and nitrogen (forming anions) (Huheey, et al, 1993).

In a fully ionic compound, an electron or electrons are transferred from one element to another, to give positive and negative ions. Sodium chloride (NaCl), which is a good example of ionic compound, consists of the ions Na^+ (the sodium atom less one electron) and Cl^- (the chlorine atom plus one electron). It is impossible to identify discrete molecules in compounds of this kind. In the solid state the ions are held together by electrostatic attraction; in aqueous solution the ions, surrounded by water molecules, are free to move about, even in the vapour phase the compound consists of ion-pair, not molecules.

Covalent Bonding

Covalent bonding results from simultaneous interaction of a pair of electrons (or, less frequently, just one electron) with two atomic nuclei. The simplest example is the hydrogen molecule, where each atom contributes one electron to the bond. This may be represented using Lewis symbols as

H$^{\cdot}$ + .H ⟶ H : H or H-H

A clearer picture of this reaction is obtained by considering the overlap of the electron orbitals of the atoms concerned. Where the electrons overlap there is a region of increased electron density (negatively charge), towards which the positively charged atomic nuclei are attracted. There is a position of minimum potential energy, where inter nuclear distance is such that this attraction and the repulsion between the nuclei are just balanced; thus the bond has a definite length and strength (Arene and Kitwood, 1982; Schubert and Veguilla-Berdecia, 1973; Engel and Reid, 2006; Brown et al, 2009).

To form a covalent bond each atom must have an unpaired electron; alternatively, one element may contribute two electrons to form a co-ordinate bond. For example, each atom of hydrogen has a single 1*s* electron, whose orbital is spherical. In a hydrogen molecule, those two electrons occupy a molecular orbital, which involves both nuclei.

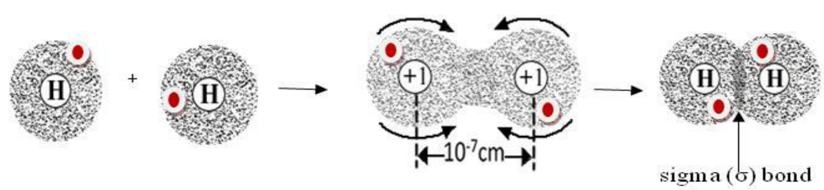


Fig 17 Bonding in hydrogen

Covalent bonding of this type occurs through orbital overlap along the axis joining the two nuclei, to give an orbital that is symmetrical about this axis. The type of covalent bond formed through this process is known as sigma (σ) bond. It occurs through *s*-*s* orbital overlap, through *s*-*p* overlap, and through overlap between *s* or *p* and hybridised orbitals. Bonding in hydrogen is very relevant to this study and is treated in the next section.

Bonding in Hydrogen

Hydrogen is the first element in the periodic table. It has the simplest atomic structure of all the elements. Hydrogen has a nucleus with a positive charge (+1) and one orbital electron and has little tendency to lose this electron in a chemical reaction. It has a great tendency to pair the electron and from a covalent bond. Hydrogen can also gain an electron and so form a negative ion, but this is only possible in a reaction with highly electropositive metals.

The hydrogen molecule (H_2) exists in two different forms know as *ortho* and *para* hydrogen. The nuclear spins of the two atoms in the molecule are either in the same direction or in opposite directions and give rise to spin isomerism.

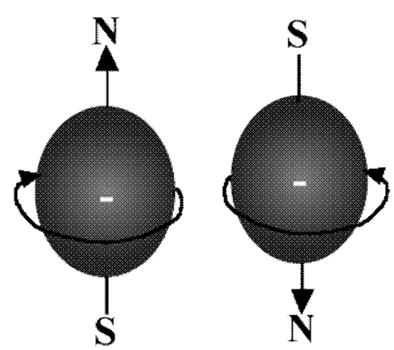


Fig 18 Direction of spin of electrons in a hydrogen molecule

There are differences between the physical properties (e.g. boiling points, specific heats and thermal conductivities) of the ortho and para forms, resulting from differences in their internal energy. The para form of hydrogen has lower energy (Lee, 1979).

Electronegativity and Dipoles

When a covalent bond connects two different atoms, for example, in the formation of hydrogen fluoride, HF, the Lewis structure is

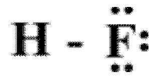


Fig 19 Lewis structure of hydrogen fluoride, HF

In this compound, the two electrons in the bond do not remain equidistant from the two nuclei; they are closer to the F atom than to the H atom. That is, the electron cloud is distorted as shown in Fig 20, because the F atom attracts the electron pair of the bond more than the H atom does.

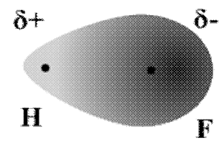


Fig 20 Distortion of electron cloud in HF molecule

This means that fluorine has a higher electronegativity than hydrogen and so attracts the electrons of the bond more. Electronegativity refers only to the attraction that an atom has for a pair of electrons in a covalent bond to itself (Bettelheim and March, 1991).

In this review, two models of the atom, the Bohr model and the quantum mechanical model emerged. The two models of the atom will be used in this study to explain what happens in chemical reactions in which new bonds are formed. The review of the nature of the atom will help the researcher in designing the shape, structure, size and speed of the models of the atom used in this study. For example, in deciding the speed of the atoms or the sub-atomic particles, during the animation of the models, the Heisenberg uncertainty principles have to be taken into consideration.

The Heisenberg uncertainty principle is better expressed mathematically as follows:

$\Delta x \, . \, \Delta(mv) \geq h/4\pi$

Where h is called Planck's constant and has a value of 6.626 x10^{-34} joule second (J-S);

Δx is the uncertainty of the position; and

$\Delta(mv)$ is the uncertainty in momentum (Sharpe, 1992).

Precisely, the Heisenberg uncertainty principles states that the position and momentum of a quantum mechanical particle cannot be known exactly and simultaneously (Engel & Reid, 2006). Momentum is the product of mass (m) of a substance and its velocity (v).

This consideration was necessary in order not to give the impression that the speed and position of the electron can be ascertained at any point in time during the chemical reaction in which bonding is taking place. The review explained the distortion of the shape of the electron cloud when new bonds were formed, and this fact was reflected in the models used in this research.

In classrooms, as literature (Ogunsola-Bamidele,1998; Ude, 2012) has shown, teachers use the lecture method to teach students chemical concepts, including the concept of atom, its structure and chemical bonding. The students in the first year of senior secondary schools in Nigeria are adolescents of the age range of 12 and 19 years. This group of students are in transition from concrete thinking to abstract thinking (Lambert and McCombs, 1998 cited in Beamon, 2010), which perhaps explains why they find it difficult to understand chemical bonding. Chemical bonding by its nature requires thinking, reflecting on and reasoning about abstract concepts and ideas. To make the teaching and learning of chemical concepts, such as chemical bonding less abstract, the use of educational software packages and other ICT devices has been suggested (Olayiwole, 2005; Ifeakor,2005).

Concept of E-Learning

E-learning, also known as computer-aided learning, refers to remediation, instruction, or teaching presented on a computer. This is also true of web-based learning. A typical e-learning programme incorporates certain functions including assessment of students' capabilities with a pre-test, presentation of educational materials in a navigable format and assessment of students' progress with a post-test. E-learning is the current approach to pedagogy and is consistent with expectations and values of the 21st century society.

The 21st century society is a knowledge society and requires possession of special skills for individuals to be relevant and play active roles therein. Voogt (2003, 2008) observed that the pedagogical approach that is important in the 21st century is that which includes among others, providing variety in learning activities, offering opportunities for students to learn at their own pace, encouraging collaborative work, focusing on problem solving, and involving students in the assessment of their learning. These, precisely, are the features, which advocates present use of e-learning and why educators have adopted it for 21st century learning. Voogt, Knezek, Cox, Knezek and ten Brummelhuis (2011) explained e-learning as learner-centred approach to education.

In the present study, the effect of e-learning via an educational software package on students' interest and achievement in chemical bonding will be determined.

Concept of Software

Software refers to the programs, instructions and commands stored in the computer. Software could be produced for a variety of purposes. The three most common purposes are to meet specific needs of a specific client/business, to meet a perceived need of some set of potential users, or for personal use. For example, a scientist may write software to automate a mundane task, just as a science educator may write a software for teaching a specific scientific concept such as chemical bonding, as is the case with this research project.

There are two groups of software - system and application software. System software consists of all the programs, language and documentation supplied by the computer manufacturer. This type of software is required to use the computer efficiently and conveniently. System software programs allow the application developers to write and develop their own programs. Examples of system software include Operating System (Window 98, Window XP), drivers (sound card drivers, display driver), viruses etc. Application software is any software, which is designed to accomplish a specific task like accounting, typing, drawing, browsing the internet, e-mailing etc. Examples of application software include MS Word, MS Excel (Gupta, 2008). The software developed in this study for the teaching and learning of chemical bonding is an example of application software. This particular application software is known as educational software package.

Educational Software Package

An educational software package is one that teaches particular skills and knowledge usually narrowed to a specific content area and level or grade range. It helps teach and learn, using the computer to assist the teaching-learning process. Educational software packages usually come with content goals and knowledge built in, and are tailored 'to fit the difficulty level and topic needs of the user' (http://www.wcu.edu/ceap/houghton/learner/look/CA.html).

In the present study, effort will be made to build into the educational software package being developed, those features that will arouse and sustain students' interest in the concept. For instance effort will be made to simplify the language in the software, the chemical species involved in the chemical combination process will be animated to enable the students conceptualise and visualise the reaction.

Theoretical Framework

Teaching and Learning

Teaching, which is the work of a teacher is causing someone (a learner or student) to acquire knowledge, skills and or modify his/her behaviour. Several authors have advanced various arguments and explanations in an attempt to make clear the meaning of teaching as a concept. While Bamisaiye (1985) is concerned with the analytic examination of the concept as well as a normative postulation of the methodology to be used, Akinboye (1985) presented the concept in terms of strategies of practice and the knowledge acquisition involved. To the former author, teaching is the most specialised activity in fostering education in the learner. It is offering a learner a reasonable opportunity to achieve understanding. Teaching involves teaching something to somebody at a given point in time or over a period. In this definition, teaching has been examined in relation to learning, in line with the popular approach adopted by many other scholars in examining the concept. Pearson Education (2003) sees teaching as the work or profession of a teacher and the word, teach, as giving lessons in school, college, or university, or helping someone learn about something by giving them information; showing someone how to do something (e.g. how to swim); showing or telling someone how they should behave or what they should think.

It follows from the later explanation that teaching (which is the work of a teacher) is causing someone to acquire knowledge, skill and or modify his/her behaviour. This implies that the work of the teacher is not limited to dissemination of knowledge but goes on to educating the learners. It is therefore difficult to discuss teaching to the exclusion of learning, for as we have seen, the two concepts are correlated. It can be said therefore, that the activity of teaching involves the teacher (the one who teaches) and the learner (the one who learns) in a form for interpersonal influence aimed at modifying the behaviour potential of an individual.

Learning as a concept belongs to two somewhat related disciplines, Education and Psychology. While educationists may see learning from the popular point of view as acquisition of specific knowledge items, particularly as a result of exposing an individual to certain environmental situation, psychologists see learning as a relatively permanent change in behaviour arising from experience (Okoye, 1987). Gardner (1991) cited in Beamon (2010) sees learning as a continuous, natural, intuitive and universal human capacity that enables the individual in the process of constructing meaning from information and experience. The learner, depending on his or her interest, motivation, perceptions, skills, previous knowledge, social interaction and situation context, in addition to personal beliefs, dispositions and emotions, controls this process of learning. There are three process stages, which are '*sine qua non conditio* for learning' (Okoye,1987:7). These are acquisition, retention, and recall, which follow a sequential order.

In the present work, learning is defined as an essential process-working tool for acquiring factual knowledge, skills, competencies, certain desirable ideals that bring about attitudinal change when learners have been involved in certain activities, from which they acquire new experiences.

Relationship between Teaching and Learning

Learning in the context of this study is the process of constructing meaning by the learner, from information and experience made available to the learner by the teacher. Teaching and learning are correlated, and in a teaching-learning process there exists interpersonal influence, which could lead to the modification of the behaviour, for instance attitude of both the teacher and the learner towards each other. The teacher for example, could be influenced by the students' reactions to a particular teaching method, to re-examine and change the teaching method in order to bring about positive attitude on the part of the students. Such positive attitude and interest could help the students in learning the concept (chemical bonding) without much stress.

It is in the context of this explanation that Olagunju (1986) asserts that learning occurs when there is a change in the learner's behaviour relative to the person's experiences, which occur within the learner's environment or social context. Okoye (1985) sees the term behaviour as a psychoneural reaction to a given stimulus. Akinboye (1984) describes behaviour as a response of the neuromotor system to environmental contingencies. Nwokeogu (1986) sees behaviour as the most variable of all the human characteristics. There are two kinds of behaviour, learned, and inherited behaviour. When behaviour is inherited, it is referred to as 'reflex behaviour' or 'respondent behaviour' and this is involuntary and genetically determined. The learned or acquired behaviour comes through experience within the learning environment. Hebb (1960) noted that heredity, by itself, can produce no behaviour whatever, and that learning can produce no behaviour by itself, without the heredity and the prenatal environment that produce the structures in which learning can occur. The two collaborate.

The point is that the environment bears on the behavioural pattern of both the learner and the teacher in any teaching-learning process. For example, the environmental situation can facilitate or impede the teaching-learning process. A teaching-learning process that obtains in a congenial and favourable environment is bound to lead to effective teaching on the part of the teacher and meaningful learning on the part of the learner. This, however, is not to the exclusion of the hereditary factors, which are the unconditioned reflex foundation upon which the behaviour of the individuals involved in the teaching-learning process is built, with the environmental factors playing a vital interactive role. Therefore, emphasis should be placed on the provision of congenial and favourable environment, especially in the classrooms and laboratories where, in a school setting, the teaching-learning process is designed to take place.

This is not to say, however, that teaching and learning take place only in the classrooms and laboratories. In fact, teaching and learning can take place anywhere and at any time, insofar as there is communication between the teacher and the learner. As Davis (1977) observed, teaching take place when information (or some skill) is communicated from the teacher to the learner. Teaching, as can be inferred from the various definitions and explanations given in the various works, so far reviewed, can be a task, an achievement or performance and involves imparting of experience. Certain conditions or factors that bear on teaching have been identified (Bamisaiye, 1985). These are personal and environmental conditions. The personal factors that favour teaching include: the intellectual ability of the teacher, that is his or her level of educational attainment; psychological attitude to teaching; and his or her subject mastery.

The more learned a teacher is, the more he or she is likely to teach effectively. The psychological state of the teacher's mind is also vital and bears on the way he or she teaches. If the teacher loves teaching, and is happy with it or because he or she derives special benefits from it, the teacher will be more enthusiastic, and in a better position to do his or her job more satisfactorily. The teacher's level of spiritual and moral development bear also on the way he or she teaches. A teacher who fears and believes in God would probably regard his/her teaching job as a sacred duty; the students as children entrusted to him by God for proper education and moral upbringing and therefore has the obligation to teach the students very well, in a morally acceptable manner. On the other hand, a teacher who neither fears nor believes in God and has the reputation of a 'wicked' person may succeed in disseminating knowledge to the students while his or her reputation is at variance with and indeed may work against the educative value of his or her teaching. The teacher must be well grounded in his or her subject as well as the relevant pedagogic principles and skills. There must be a deliberate effort towards inculcating a positive life outlook in the learner.

Teaching and learning do not take place in a vacuum but in both physical as well emotional environment in a teacher-learner relationship. The teacher must be psychologically as well as intellectually prepared in order for him or her to be effective in carrying out the teaching activities. In addition, there must be adequate supply of basic facilities needed for the teaching activity. Again, the prevailing atmosphere in which the teaching-learning process is taking place must be conducive and devoid of unnecessary discomfort and distraction.

In the context of this study, the computer provides and modifies the physical learning environment. Computer-assisted instruction helps in restructuring learning environment by engaging the students with computers, through which the learners receive instructions on the screens and make appropriate responses through the attached keyboards. Depending on the learner's responses, the stored programme in the computer varies its sets of instructions to meet individual learners' needs. With regard to the emotional environment of teaching, there must be a cordial relationship between the teacher and the learner and between them and other stakeholders in the teaching-learning situation, for instance parents, fellow teachers, and the school authorities.

Evaluation of Teaching and Learning in Chemistry Education

Evaluation is a necessary component of the teaching-learning process. Evaluation is 'a value judgement of the effectiveness of an educational enterprise' (Thorndike and Hagen, 1969:647). With regard to chemistry education, Oriaifor (1993) pointed to the usefulness of evaluation in taking decisions about the scope and adequacy of student's needs. The author described evaluation as 'a procedure that is usually aimed at discovering the extent to which educational objectives are congruent with observed or expected reality'. The author noted that evaluation is applied for

i. Better understanding of the subject

ii. Overall improvement of content, methodology and resources; and

iii. Effectiveness of decision-making on student performance and related educational objectives (p.144).

In an educational setting therefore, evaluation refers to the judgement of students' progress and includes valuing, that is, deciding and saying what is desirable and good. Evaluation of students' progress is a major aspect of the teacher's job. The teacher appraises student's understanding, skill, attitudes, interests, ability to apply and achievement. Teachers use tests as the tool and basis for evaluation. In this regard, the role of the teacher in the overall evaluation process becomes very crucial and makes demand on the teacher's skill and knowledge of evaluation technicalities. Oriaifor (1993) observed that evaluation in chemistry education is not limited to the progress or performance of the students but extended to

i. Materials, including textbooks, audio-visual materials and other materials necessary for improving teaching and learning of chemistry;

ii. Methods or teaching styles for effective teaching and learning of chemistry; and

iii. The school itself, its traditions, its physical facilities and its administration

iv. Administration in this case, includes individual chemistry teachers and laboratory attendants and their policies.

In respect of the above, the author recommended that periodic judgement for effectiveness and competence should be carried out and decisions along this line taken towards the improvement of students' performance as well as the entire administrative regulation.

Evaluation as a necessary component of the teaching-learning process has implication for the teacher. For the teacher, evaluation has a dual value: it is carried out to enable the teacher assess the success or otherwise of the lesson taught, that is, to find out if the learner has learnt. It also helps the teacher in re-assessing his or her method of teaching. Through evaluation, the students carry out a self-assessment of their performance on a given learning task, with a view to identifying their strengths and deficiencies and seeking solutions to those areas of it where they need to improve upon. Evaluation helps the teacher to determine how effective his teaching is and when and where to adjust his teaching methodology for improved pedagogic performance (Okoye, 1987). All this is geared towards bringing about meaningful learning on the part of the learner and ensuring competency and effectiveness on the part of the teacher.

Criteria for Evaluation of Teaching and Learning

Bamisaiye (1985) opined that the primary relationship between the teacher and learners is an activity relationship. In this relationship, the task of the teacher in teaching implies the task of the learner in learning. Learning in this case is regarded as part of the continuum of teaching, which implies that whatever learning is achieved results from teaching. Therefore, the task of teaching leads to the task of learning and to the attainment of learning, which is the achievement of teaching. The extent of accomplishment of learning should constitute the yardstick for evaluating the success or otherwise of teaching.

Evaluation of teaching can be a complex exercise, especially if it is realised that teaching entails more than just causing the learner to learn in the sense of retaining the body of knowledge made available to him or her by the teacher. The teacher is not just a knowledge disseminator but also a motivator, someone ‘to awaken the intelligences within learners’ (Hoffman, 1991:3); the veritable educator and personality development agent. Therefore, teaching should be evaluated not only in terms of how much a learner has been equipped with either factual knowledge or certain skills, but also in terms of whether it is educative. To be educative, teaching should not only equip the learner to acquire facts or skills, but should go on to create further knowledge that enables the individual to develop certain life principles that would strengthen him or her in forming and maintaining positive social outlook (Langford, 1979). Therefore, for teaching to lead to education, it must be carried out in such a manner that aims at developing in the learner those attributes of an educated person, which include acquisition of specialised body of knowledge or skills, development of positive social outlook, ability to exploit such knowledge or skills for personal and social welfare (Bamisaiye, 1985).

From the point of view of the above explanation, the effectiveness of learning in this context should be evaluated based on specific knowledge and skill acquisition level attained by the learner in the teaching-learning process, and in terms of intended learning outcome or objectives stipulated in the curriculum or lesson plan for the learning programme. In the present study, the performance objectives set out for the teaching of chemical bonding were used in evaluating the students’ understanding of the concept. The students are mainly adolescents.

Adolescent Learners

Adolescent learners are those between the ages of twelve and nineteen years. This group of children forms the bulk of students found in year one classes of our senior secondary schools in Nigeria. They are curious, motivated to achieve when challenged and are capable of critical and complex thinking. *Turning points guide* (2010) described adolescent learners as energetic, eager to learn, curious, adventurous, sociable, and extremely honest. Lambert and McCombs (1998) as cited Beamon (2010) observed that adolescent learners are in transition from concrete thinking to abstract thinking; developing the capability to analyse and understand real life experiences as they think, reflect on, and reason about abstract concepts and ideas.

Adolescent learners have wide range of interests and intellectual pursuits, few of which are sustained over a long period. They build on prior knowledge and learn easily when they are motivated. They are able to see the relationship between what they are trying to learn and what they are familiar with. They learn better, when the concept to be learnt involves interactive, purposeful and meaningful engagement, in a supportive environment, where value is given to personal ideas and negative emotions, such as fear of punishment and embarrassment are minimised. They are very sensitive, emotional, and often hold on to their personal feelings of anger or embarrassment. Beamon (2010) observed that the perspectives of adolescent learners remain predominantly 'me centred' and limited, and recommended teaching methods that provide the young learners activities and opportunity to choose and pursue their own interests while applying their knowledge and skill in cooperative learning under the teacher's watchful eyes. They should be allowed time for self-appraisal and reflection and encouraged in a one-on-one chat to express their individual difficulties where they need help, to enable them adjust and learn better.

This underscores the need to provide interactive learning environment, which allows each student to work privately at his or her own pace, make mistakes, and learn from such mistakes without fear of punishment or embarrassment. Ebem and Inyama (2005) and Okoroafor and Okoroafor (2010) assert that using multimedia in teaching-learning processes can provide such environment. The questions then that agitated the mind of the researcher were : How will the educational software package being developed for the teaching and learning of chemical bonding be constructed such that it could provide the expected interactive environment that will enhance the teacher's effectiveness and promote students' meaningful learning? What will be the effect of the educational software package on students' interest and achievement in chemical bonding? These and other similar questions inherent in the use of multimedia in the teaching-learning process of chemical bonding guided the researcher while designing the software package.

Theories of Instruction and Learning

A theory is general principles and ideas about a subject (Pearson Education, 2003:2008) while instruction is the deliberate intervention in or channelling of the learning process (Ing, 1978). It is formal teaching that is given in a particular skill or subject (Pearson education, 2003: 988). Two theories of instruction, Gagné (1974) and Bruner (1966) are found relevant in the present study.

Bruner's and Gagné's Theories of Instruction

Bruner (1966) in his work: *Towards a Theory of Instruction* gave the essential features of a theory of instruction. These features include: *predisposition, structure, sequence* and *reinforcement*. For predisposition, a theory of instruction should specify the experiences and conditions that make a person receptive to learning. In the case of structure, a theory of instruction should specify the optimal structure of a body of knowledge, relative to the learner's age, ability and experience, in order that it can be most easily learned by the individual. Ing (1978) explains that by structure, Bruner was referring to the power of systems in knowledge to simplify information, to generate new propositions and increase the manipulability of what has been learned. For sequence, a theory of instruction should specify the most suitable and effective sequences in which the concept or lesson should be presented to the learner; while for reinforcement a theory of instruction should specify the nature and spacing of reinforcements in the teaching-learning process. Bruner is of the view that the use of extrinsic incentives should be replaced by more intrinsic rewards.

Gagné (1974) in his work: *Essentials of Learning for Instruction* offers specific strategies for the teacher intervention and influence in the classroom. He assumes that decisions about what is to be taught will already have been made before the individual teacher puts into practice his instructional principle. Gagne asserts that a course or lesson is usually concerned with more than one learning outcome, and suggests a checking procedure to ensure that all the desired outcomes have been covered in the planning of instruction, and a series of 'outcome questions' which are really behavioural objectives.

Bruner's and Gagné's theories of instruction derive from their theories of learning and have implication for the design and development of a teaching software package and in the case of this study, the development of chemical bonding instructional software package (CBISP) and other instructional materials development. First, the software (CBISP) should be concerned with the process of teaching, that is, presentation of subject matter, such that what is taught should increase the power of learning. Second, the subject matter in the software should be simplified and 'complete' and interesting such that its usage should provide the intrinsic reward which reinforces learning on the part of the user.

For this reason, in the design of the CBISP, consideration will be given to the previous knowledge of the students; and the lessons in the software package shall be simplified such that students will find the lessons very interesting. The lessons should be such that every topic necessary for the students to meet the objectives and recommendations of the curriculum for the concept of chemical bonding would have been covered. In other words, the lessons in the software package should be complete.

Theories of Learning

Theories of learning present a systematic picture of learning processes and of the conditions more favourable to learning. They make explicit the implicit notions embedded in the actual practice of teachers (Ing. 1987). Ortyoyande (1992) opined that theories of learning enable the teacher to consider and assess the various aspects of a learner's behaviour and see how these could be taken advantage of in helping the person to learn.

Learning theories may therefore be regarded as interrelated constructs, propositions and definitions that present a systematic view of what is known about the teaching-learning processes, intended to provide a practical guideline to the teacher in evaluating effects on the behaviour of the learner, of certain experiences provided by the teacher in the course of teaching. Gagné, Bruner and Ausubel's theories of learning are found relevant in this study.

Gagné, Bruner and Ausubel's theories of learning

Gagné (1970) categorised learning and sub-divided intellectual skills into hierarchical sequence, and suggested that teaching should follow this sequence in order to be effective. In his information-processing theory of learning, Gagné (1974) made a basic assumption that learning processes are analogous to the working of a computer, and its focus is on the transformations which occur between the inputs of external stimuli and the output of the learner's behaviour. Gagné outlined the events of learning; to classify the outcomes of learning; and to categorise the ways in which the teacher can influence the stages of learning. Gagné identified motivation, prior knowledge, reinforcement and knowledge of the results (objectives) of lessons which shows the learner whether he has reached his goal as key to learning. The author also identified three aspects of teaching which can benefit from such knowledge. These are: first, the planning of courses, curricula and lessons; second, the conduct of instruction; and third the assessment of what has been learned.

Ausubel (1960; 1963) in his own theories of learning dealt with meaningful verbal learning in which he suggested that teaching should relate new information to fit into an existing cognitive structure. To Bruner (1966) there is the need to place emphasis on relating incoming information to previously required frame of reference. He stressed the importance of the activities of the learners who are expected to transform the incoming information, constructing or rejecting hypothesis while relating this information to the existing structure in the mind.

Knowledge of learning theory helps the teacher to direct his/her efforts to influence learning in an effective way. For instance, Gagné identified three aspects of teaching which can benefit from such knowledge. These are: first, the planning of courses, curricula and lessons; second, the conduct of instruction; and third the assessment of what has been learned. These theories of learning have been applied in designing and planning of the lessons to be used in this study. The theories enabled the researcher to consider what the learners need to enable them learn chemical bonding, how this new concept is related to their past experiences, and whether the students would perceive and understand what would be studied and above all whether the relevance of the learning would be clear to them.

E- Learning: Use of Computer in Education

The use of computer in education started sometime in the mid-1960s (Glennan and Melmad (1996). During this period, educators showed interest in the use of computers for classroom teaching, but had their misgivings about this new technology. For instance, there was this fear that the computer will impose a rigid and impersonal regime on the classroom and even replace teachers (Suppes, 1967). Because of this fear, Barrett (1968) noted that it would take a long process of education and motivation to make the teachers realise and accept the contributions that computers could make to education. Barrett (1968) advised that teachers must learn to turn over much of their rights, duties, and responsibilities to the computer over which they have little control and towards which some of them were hostile. With the advent of microcomputer in the 21st century, the use of computer in institutions of learning has become widespread from pre-primary education through the university level. Computer-aided instruction or e-learning has indeed come to stay.

Indeed, the emergence of basic technology infrastructure and tools for learning in the 21st century resulted in new learning processes and augmented capabilities that learners have through the use of such tools (Voogt, et al 2011). This forms the basis of e-learning and explains its primary role in 21st century learning, especially towards acquiring 21st century skills. It is interesting to observe that the initial resistance or hostility to computer-assisted instruction or e-learning shown by some teachers appears to be outdated, at least in those nations where computer has been in use in the school system for many years now. This may not be the case with teacher in developing nations where e-learning is new. In the present study, which aims at finding out the effect of e-learning via an educational software package on students' interest and achievement in chemical bonding, the co-operation of teachers with knowledge in basic computer operations will be needed.

E-learning and Educational Software Packages

E-learning is made possible and meaningful because of availability of educational software. Educational software is software that facilitates teaching, using the computer to aid the instructional process. Educational software packages come in increasing variety of forms. Houghton (2008) point to increasing use and power of computer technology in schools, and advised that educators must know what educational software is capable. This is important because when the teacher is able to understand the role of software in the classroom, learning becomes interesting and meaningful. As Baker (2011) noted, educational software can be a powerful tool when used by teachers who understand that technology is the vehicle and not the message.

Literature is replete with views of pioneer researchers in e-learning as regards the advantages of use of computer in education. For instance, Suppes (1967) projected among others, that the computer would relieve teachers of some of the burden of preparing and correcting large numbers of individualised drill-and-practice exercises in basic concepts and skills; and of recording grades. Researchers that are more recent have confirmed this and other advantages. For example, Houghton (2008) mentioned many other advantages of the use of computers in learning including its power to evaluate in less interruptive way and record frequent data on students' progress.

In spite of the numerous advantages, which advocates associate with e-learning, Hartmann (2004) asserted that studies and reports, which promote e-learning are very often not research evidence-based, but are rather doctrine-based. The author points to the controversy that exist among educators as to whether computer supported learning is better than learning in conventional environments such as in a classroom or from a textbook. The result of the present study might throw some light that could help in resolving the above controversy.

Theories of Software Development

Development of software entails all the activities involved between its conception through to the final manifestation of the software. Software development refers to the art of working or work that is accomplished through the design phase to the manufacture of the software (Mbam, 2005). Software development may include research, new development, modification, reuse, re-engineering, maintenance and indeed all activities that result in software product. It may also include the writing of its application programming interface (API), which includes features (both external and internal) that let the developer maintain user-specific and application-specific settings in a standard way to store short configuration values in an open and easy-to-understand text file format (Patrick, 2008). The design process involves an examination and or analysis of the software user's needs and massaging those needs into the software product.

The primary user is one party and plays a crucial role in the development of the software. The role includes specifying the feature of the software, reviewing prototypes of specific portions of the application and testing *beta* version of the nearly completed product (Patrick, 2008). The other party to software development is the programmer whose role is to design, document, develop and deliver the software.

To enable the programmer draw up a **design document**, the programmer may have to conduct a general user interview with several user candidates, in order to determine a representative perceived user and the needs of such intended target user. The design document serves as a guide in building the software or **application**, which is another term for software. The researcher uses the terms interchangeably in this study. Software development is targeted at an application that is user-friendly and can interface with database application and meets user's needs. This is done by examining current data and procedures helpful in gathering the details required to craft the right solution.

Patrick (2008) categorised user's needs into five parts namely, data and information, processes usability, commonality, and project-specific needs. These needs are explained as follows. *Data* is the raw information stored in the program; names, number, images, or any other standard value. *Information* is data in context: a customer, properties of types of bond as in the case software for teaching chemical bonding, which is being proposed. *Process* is the presentation of data and information in an appropriate sequence at a given time, in a format that is both *usable* and accessible. A software is usable only if it can run on a computer. The ease and usability of a software depends on the ease and usability put into the programs. Patrick (2008: 80) noted that 'ease of use for the user always means more work for the developer'. He asserts that the core need of users is the need not to be overwhelmed, by new ways of doing task they thought they already could do (p. 83). Users need consistency. The developer can ensure consistency by making the programs retain some commonality with the operating system, and with other installed programs.

There are needs that are specific to each software project, which require an understanding of the objectives the task that the user needs to accomplish with the desired application. It is necessary that developers document and design the software to meet these project-specific needs. An example of a software that is project-specific is the software for the teaching of chemical bonding that is being proposed, which will facilitate the teaching of chemical bonding, and make instruction meaningful to beginning (SS1) students at the secondary. It should aid the students to visualise chemical bonding process, understand the subject matter and be able to explain the concept in concrete terms, using their own language. Gardner (1995:56) stresses on the importance of visual communication and asserts that as ‘society advances, it relies less on text and more on visual communication’. Students, therefore, are likely to benefit more from visual communication, via the computer. Thus, a solid foundation would be laid for the students’ further studies in chemistry. A good understanding of chemical bonding is key to making progress in further studies in chemistry.

Software Development Process

A *software development process*, also known as *software life cycle* or simply *software process*, is a structure imposed on the development of a software product. It is necessary to understand from the outset that these terms are synonymous. In this study therefore, the researcher uses the terms interchangeably in discussing the management of software development project.

Patrick (2008) noted that projects have a lifetime all their own, some are short-lived while some go on forever, with continual improvements made over a series of version iterations. It is necessary that a software developer be aware of the lifetime of the project. This helps the developer apply business processes to each major phase of the project's life. The developer needs to have skills, collectively called **project management**, to guide the project to its conclusion, or through each successive version of the project.

Models of Software Development

There are several models for developing a software, each of these models describe approaches to a variety of tasks or activities that take place during the process that give rise to the manifesting of the software. Some software development processes include: waterfall model, cyclical or iterative model, prototyping software development life cycle model, iterative enhancement model, the spiral model, object oriented methodology, and dynamic system development model. (*www.coleyconsulting.couk/waterfallmodel)*. These software development models may be grouped into two basic approaches to project management: cyclical or iterative and the linear approach (Fig 21).

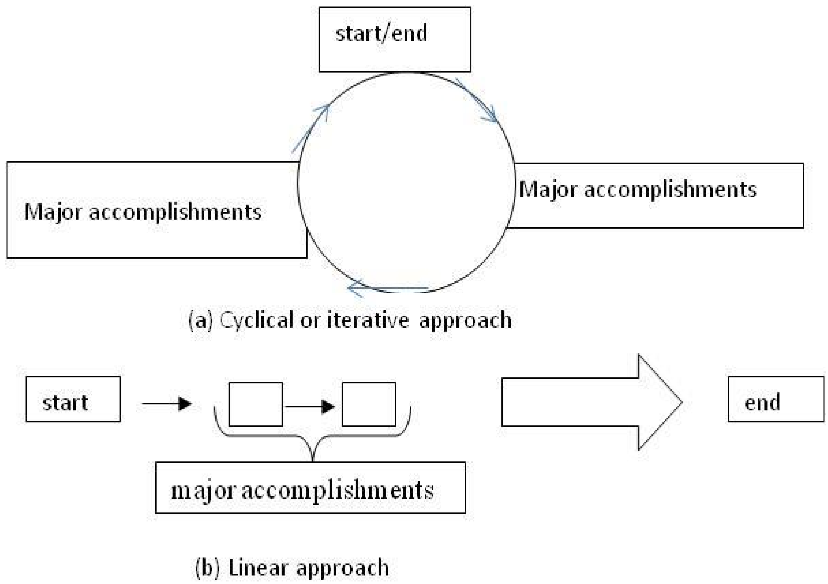


Fig. 21 Cyclical and Linear approach to management of software project

Patrick (2008:84) noted that irrespective of the developer's choice, 'several major events happen between the start and end of the line or iteration, beginning with the project kickoff, which marks the official start of the project'. The kickoff simply is the initial schedule for information and resource gathering.

The choice of the developmental model is entirely that of the developer and depends on the kind of software product aimed at, and on other factors that must be considered in the development. For instance, the developer needs to consider if the model is less capital intensive, in terms of time and finance; if it is easier to use than the next alternative model. The Waterfall model, which is found relevant in this study is reviewed.

Waterfall Model of Software Development

The waterfall model of creating a software is one that organizes various developmental phases in a linear order that progresses, systematically from one phase to another in a downward fashion, like a waterfall. The developmental phases are: requirements, design, implementation, verification and maintenance arranged in the following order (Fig 22)

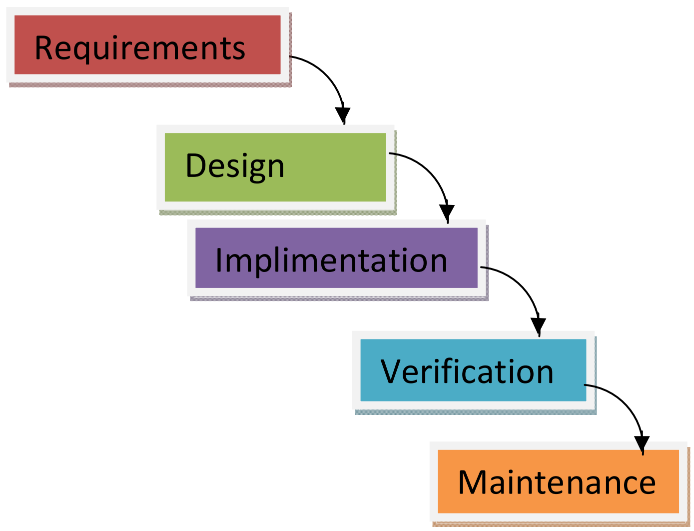


Fig. 22 Waterfall Model of Software Development

With a waterfall model, the production of the software is taken from 'the basic step going downwards detailing just like a waterfall, which begins at the top of the cliff and goes downwards, but not backwards' (http://www.waterfall model.com).

The activities performed are requirements analysis, project planning, system design, detailed design, coding and unit testing, system integration and testing. Coley consulting (2012) noted that with the linear ordering of these activities, the end of one phase and beginning of the others can clearly be defined and easily identified. This means that each phase must have some defined output that can be evaluated and certified. The certification mechanism used at the end of each phase consists in verification and validation. Validation means confirming the output of a phase is consistent with its input (which is the output of the previous phase) and that the output of the phase is consistent with overall requirements of the system. Therefore, activities of a phase are considered completed when there is an output product of that phase; the goal of a phase in to produce this product. The outputs of the earlier phases, which Patrick (2008) termed interim deliverables are also called *intermediate products* or design document. Coley consulting (2012) noted that the output of a software project is to justify the final program along with the use of documentation with the requirement document, project plan, test plan and test result.

The waterfall model is unique and has the following advantages

(i) It requires the fulfillment of one phase of the project before proceeding to the next;
(ii) It emphasises paperwork that documents the developmental process, which make it easier to understand what step is going to follow next.
(iii) It is a straightforward method that lets the user know easily what stage is in progress.
(iv) It is easier to use in developing software in a short span of time (http://www.waterfall.model.com).

Coley consulting (2012) asserts that 'the simplest software development life cycle model is the waterfall model'.It is in consideration of the unique features and advantages of the waterfall model that the researcher considered it most suitable in this study. However, it is necessary to note that an adapted version of this model shall be used in this study.

Software development project has a lifetime, which starts with **documentation.** This is a phase where everything that will be done in the course of the entire project, especially in the design stages, is made. The document reminds the developer of essential aspects of the project during the development phase. The documentation should be precise, proper and complete, and aimed at producing two main documents, the main project design document (from which the application will be built), and the schedule (which lets the progress during the project be gauged).

The projects goals help determine its scope, the extent of the features and supporting materials that will be produced during the project's lifetime. Gottfried (2001:184) defined scope as 'the portion of a programme within which a procedure definition (or a variable or named constant definition) is recognised'. Determining scope is crucial; it sets the constraints, the limits that will keep the project from going out of control (Patrick, 2008).

The **Design** and **Planning** phase follows the documentation phase. During the design phase, the developer plays the role of an architect, a designer who set down on paper precise details on how to construct the software. At this stage, many details, although not everything is put in this construction plan or the blueprints. The blueprint gives the specifications. This is the level of details in the design that can be turned into a software creation. Whatever level of detail included in the plan, the plan should contain 'certain key events that will happen throughout the entire project schedule. These milestones identify interim deliverables, results expected at specific moments throughout the timeline of the project' (Patrick 2008:86). Deliverables are those items produced as a result of a project. They generally include software, user and technical documentation, installation media and related materials (p.85).

In the present study, the Waterfall model was chosen because it is less capital intensive, in terms of time and finance; it is easier to use than the next alternative model.

The expected deliverables are the Chemical Bonding Educational Software Package (CBESP), the Software Rating Scale (SRS) and the test report.

Review of Empirical Studies

Gender, School location, Interest and Achievement in Chemistry

The influence of gender on learning and achievement has remained a controversial and topical issue amongst educationists and psychologists. Freud (1958) suggested that the difference in male and female anatomy has bearing and indeed account for the difference observed between the personalities of men and women. It is from this Freudian theory that several gender-related studies have taken their roots. Ssempala (2005) carried out a study to determine if there were gender differences in the performance of practical skills on quantitative analysis, an aspect of chemistry, among senior secondary school girls and boys in selected co-educational schools in Kampala District. Fifty students, half of them girls and the other half boys took part in the study. The result of the study showed that:

(i) there were no statistical significant differences between girls and boys in their ability to manipulate the apparatus/equipment, take observation, report/record results correctly, and compute/interpret/analyse results during chemistry practical;

(ii) both female and male students perceived interpreting/analyzing results to be the most difficult skill to perform, whereas manipulation of apparatus/equipment was perceived to be the easy skill to perform during chemistry practical by both gender;

(iii) girls had a poor self-confidence in their ability to perform chemistry practical, as most of them (90%) believed that boys were better than them;

(iv) girls performed slightly better than boys overall, boys performed slightly than the girls in the following skills; recording/reporting results correctly, and computing/interpreting/analysing results.

Adesoji and Babatunde (2008) investigated male and female chemistry students' difficulties and misconceptions in inorganic chemistry. Result of their study showed that:

(i) both male and female chemistry students held misconceptions in inorganic chemistry;

(ii) female students had more problem-solving difficulties than their male counterparts in inorganic chemistry;

(iii) female students held more misconceptions than their male counterparts in inorganic chemistry.

Eze (2008) studied the effect of two questioning techniques on students' achievement, retention and interest in chemistry and found that

(i) gender had significant effects on students' achievement;

(ii) male students achieved higher than their female counterparts.

It would appear, from the above studies, that gender as an influencing factor in learning and achievement remains important but controversial. This is also the case with school location

In Nigeria, rural life is to some extent uniform, homogenous and less complex than that of urban centres, with cultural diversity, which affect the interest of students. The urban centres are better favoured with respect to distribution of social amenities such as pipe borne water, electricity, health facilities while the rural areas are less favoured. This is also true in the distribution of educational facilities and teachers. These prevailing conditions imply that 'learning opportunities in Nigerian schools differ from school to school' (Ariyo and Ugodulunwa, 2007:6). It would appear therefore that students in Nigerian urban schools have more educational opportunities than their counterparts in rural school have. Either studies have supported or otherwise the notion that school location influences interest of students and their learning outcome or achievement. Nwogu (2010) found that location was a significant factor in learning aspects of mathematics that involve angles, with rural students exhibiting more learning difficulties than their urban counterpart do. Ahiaba and Igweonwu (2003) investigated the influence of school location on the performance of chemistry students in rural and urban schools at the SSC examination and found that chemistry students in urban schools performed better with superior grades, than their rural counterparts while failure rate was higher in the rural schools. There is, therefore, apparent gap that is created by both gender and school location, and this gap needs to be closed. What is important, however, is the creation of a uniform condition and equal opportunity for students of both genders irrespective of location of their school, to access same lesson for which their learning outcome will be evaluated. The lesson should be such that will arouse and sustain students' interest in the subject.

Interest is the feeling one has in the cause or process of wanting to know or learn about something or someone. It is an activity which someone enjoys and spends free time in studying or doing (Ifeakor, 2005). Njoku (1997) asserts that sustenance of a person's interest in an object or activity depends on what the person stands to derive from the object or activity. In this case, there is value judgment on the part of the individual. If people in their judgment feel there is 'something' to gain or lose from an object or activity, the tendency is for them to show interest or aversion to the object or activity. It implies therefore that the degree of interest one has in a subject or activity is determined by the level of value placed on the expected 'something' derivable from the object or activity. Value judgment is usually a function of the knowledge the person who is carrying out the judgment has about the activity or object. This knowledge is acquired through encounter or interaction with the object or involvement in the activities of interest. This is very fundamental and enables individuals to increase their *primary* knowledge about the object or activities of interest to them, which in this situation remain their primary source of knowledge.

Agbi (2006) opined that students' achievement in chemistry is influenced by their interest in the subject. The author asserts that interest engenders motivation and effort, which together interact, resulting in achievement and success in chemistry. It was observed that students' interest in chemistry is diminished and dampened by use of ineffective teaching method. Teachers should therefore always make conscious effort to identify and use teaching methods that are appropriate and suitable for the level of their students. This way, students' interest in chemistry could be aroused, sustained and enhanced. It is under this condition that students' achievement in chemistry is made possible.

Eze (1992) observed that strategies in pedagogy impact on students' interest in science. One strategy that is recommended in secondary schools chemistry curriculum for 21^{st} century learning is e-learning, defined as a kind of teaching that uses computers

(Hartmann, 2004). In e-learning, educational software packages serve as multimedia platform for communication and interaction between the learning material and students. It is expected that this strategy will sustain students' interest in learning and improve their achievement in Chemistry.

Studies on Gender-related Differences in Interest and Achievement in Chemistry

Ahiakwo (1988) showed that girls performed better than boys in chemistry, and that the difference between their mean achievement score was significant. Trigwell (1990) found that male students were superior over female students in problem-solving and achievement in chemistry. Erinosho (1994) cited in Adesoji and Babatunde (2008) showed that the difference between the mean achievement scores of female and male students was not statistically significant in chemistry. Agbir (2004) found that gender was not a significant factor in the overall mean achievement rating of students in practical skills on acid-base titration. Ifeakor (2005) showed a significant gender-related difference in students' cognitive achievement in favour of male students over their female counterparts.

Ssempala (2005) investigated gender differences in the performance of practical skills on quantitative analysis, an aspect of chemistry, among senior secondary school girls and boys in selected co-educational schools. The author showed that there were no statistical significant differences between girls and boys in their ability to manipulate the apparatus/equipment, take observation, report/record results correctly, and compute/interpret/analyse results during chemistry practical; girls performed slightly better than boys overall; boys performed slightly than the girls in the following skills: recording/reporting results correctly, and computing/interpreting/analysing results. Eze

(2008) studied the effect of two questioning techniques on students' achievement, retention and interest in chemistry and found that gender had significant effects on students' achievement; male students achieved higher than their female counterparts did.

It would appear, from the above studies, that gender as an influencing factor in learning and achievement in aspects of chemistry remains important but controversial. None of the reviewed studies was on chemical bonding; this leaves a gap in knowledge, thus creating a need for this present study.

Effect of multimedia Instruction on Students' Learning Outcome

A number of studies have reported success stories and positive results when multimedia was used to enhance learning. Kulik (1994) carried out a meta-analytic studies on findings on computer based instruction and found that when students received computer–based instruction they usually learned more, learned their lessons in less time, liked their classes more, and developed more positive attitude towards computers.

Miketta and Ludford (1995) developed an interactive courseware template by integrating into classroom teaching multimedia elements to be controlled by the teacher. Their lecture notes were converted into a multimedia presentation by adding graphics and links to slides and other resources in a classroom full of passive learners. The classroom became transformed 'into a room full of active critical thinkers who probed for additional insights' (Miketta and Ludford, 1995:62). In their assessment of students' performance because of using the multimedia in teaching them, Miketta and Ludford asserted that students become more involved in classroom activities and achieve a better understanding of the lesson when it is presented in a multimedia format (p.64). In test and quiz, the students' scores when compared to previous classes moved up by seven percent points in the areas of retention and comprehension. It would however appear that Miketta and Ludford did not validate their assessment with control groups. Their work however showed that the use of interactive multimedia technologies in the classroom renewed teachers' interest and enthusiasm and increased students' motivation.

Cronin (1993) carried out an empirical measurement of learning outcome in an experimental study that investigated the effects of interactive video instruction (IVI) and found that students using the new instructional module achieved significantly higher recall and test scores than students in the control group. 'The most important outcome of these studies is the preliminary empirical documentation of the effectiveness of interactive multimedia instruction in teaching oral communication skills' (Cronin, 1993:18)

It could be concluded that the use of multimedia technologies is interesting and innovative. It improves classroom teaching and enhances students' learning. Multimedia technologies help to develop higher–order thinking skills, communication skills; they cater to multiple learning styles and student motivation. They help students to better retain what they had learned and bring about improvement in mastery of subject matter. This summarises the results of studies conducted overseas, especially in America where students have had long contact with computer and other multimedia technologies.

Effects of Multimedia Technologies on Nigerian Students' Classroom Learning

Reports on empirical studies carried out in Nigeria to ascertain effects of multimedia technologies in classroom learning are scanty. Akabogu (2010) studied the effect of computer-assisted second language vocabulary acquisition on Nigerian secondary school students' achievement in English language vocabulary. The study involved a sample of 40 senior secondary class two (SS2) students comprising 20 students each for the control and experimental groups. Using means and t-test statistics, the data on students' performance obtained in the study was analysed. The analysis indicated that computer-assisted vocabulary acquisition did not improve or enhance students' achievement in vocabulary acquisition more than conventional method of contextual deduction.

Jegede, Okebukola and Ajewole (1992) studied students' attitude to the use of computer in learning and achievement in biological concepts and found that there was no significant difference between the achievement profiles of students taught biology and those taught without computer. At the time of the study, Computer Assisted Instruction (CAI) was a novel venture in Nigeria. The authors attributed the result of their study to 'distraction' of the computer, as the students seemed to have concentrated their attention to the functions of the computer instead of paying attention to the concept , which was taught by the computer. Adeniyi (1997) , studied the effect of computer-aided instruction (CAI) on the achievement of college students in physics. In the study, 100 students of a College of Education were divided into two groups, one CAI group the other, control group. Mean scores, standard deviation and t-test were used to analyse the data obtained. Result showed that students taught with computer-aided instruction performed better than their counterparts taught without computer-aided instruction.

Effect of Multimedia Instruction on Students' Academic Interest

Ifeakor (2005) using a quasi-experimental design, studied the effect of commercially produced computer-assisted instructional package (CPCAIP) on students' interest and achievement on secondary school chemistry. The study also investigated the interaction effect of CPCAIP and gender on students' achievements and interest. The study showed that CPCAIP had significant effect on students' cognitive achievement and interest in chemistry. The interaction effect of CPCAIP and gender on students' overall cognitive achievement in chemistry was significant. CPCAIP had a significant effect on the students' interest towards chemistry. Gender was not a significant factor in students' interest in chemistry. The interaction effect of CPCAIP and gender on students' interest in chemistry was not significant. It seems from these findings that the use of computer-aided instruction is more effective in improving students' achievement and interest in chemistry. This implies that there is need for chemistry teachers to use computer-aided packages in teaching chemistry.

It is interesting to notes here that many of the studies reported in Nigeria about the effect of CAI on students' learning are on subjects other than chemistry while few on chemistry are certainly not specifically on chemical bonding as provided in NERDC chemistry curriculum tailored to suit the level and needs of SS 1 students. Among the few studies on the effects of CAI on students' learning in chemistry are those by Ifeakor (2005) and Nnaobi (2003). Ifeakor (2005) asserted that with computer-aided educational instruction, students achieved more than students taught without computer aided instruction in chemistry. Nnaobi (2003) investigated the effect of use of computer-aided instruction (CAI) on students performance in chemistry. The study specifically compared the effect of computer-aided instruction and the use of instructional materials in teaching-learning process in chemistry at the tertiary level of education. In the study the author used two non-randomised groups in a pretest and posttest experimental design. The sample consisted of 150 (90 Agricultural Science and 60 chemistry) students randomly elected from a population of 250 students in a college of Education.

The experimental group (Chemistry/Computer Science) was taught using chemistry instructional software package in form of drill and practice, in organic chemistry lessons. The control group (Agricultural students) received the same lesson but, were taught using ordinary instructional materials. The treatment lasted for 4 weeks. Traditional lecture method was used for the two groups. Instructional materials used were models, pictures and flowcharts. The two groups had the same paper-and-pencil pre-test and post-test.

Results of the study showed that computer-aided instruction had more positive effect on students' achievement in chemistry than traditional lecture method ($t = 1.963 > 0.3689$). The author concluded that computer-aided instruction enhanced students' performance a lot better than teaching with ordinary instructional material. In all the studies under review, on effects of CIA on Nigerian students' achievements in chemistry, there was no indication of the quality rating of the commercially produced software package used in the studies.

In the present study, the researcher's interest was to find out the effect on students' interest and achievement, of using an educational software package specifically designed and developed by the researcher for the teaching of the concept of chemical bonding, as recommended for beginning chemistry students in Nigerian schools, based on the NERDC curriculum for secondary school chemistry.

Summary of Literature Review

In this chapter, the theoretical concepts of teaching, learning, interest, atom and chemical bonding were reviewed. The influence of environment on students' learning; the impact of teaching method on students' interest in chemistry and their achievement in the subject were also reviewed.

In the review, teaching and learning were shown to be correlated in a form of interpersonal influence, aimed at modifying the behaviour potential of the individuals involved in the teaching-learning process. In the process, the teacher exposes the learner to certain desirable ideals that bring about attitudinal change when the learner has been involved in activities, from which new experiences are acquired. Environment bears on the behavioural pattern of both the learner and the teacher in any teaching-learning process. Although teaching and learning can take place anywhere and at any time, insofar as there is communication between the teacher and the learner, the environmental situation can facilitate or impede the teaching-learning process. A congenial and favourable environment devoid of unnecessary discomfort and distraction aids the teaching-learning process that obtains therein. Adolescent learners build on prior knowledge and learn better, when the concept to be learnt involves interactive, purposeful and meaningful engagement in a supportive environment where value is given to personal ideals and negative emotions, such as fear of punishment and embarrassment are minimised. This underscores the need to provide interactive learning environment in form of educational software packages that allow each adolescent student to work privately at their own pace, make mistakes and learn from such mistakes without fear of punishment or embarrassment. The educational software packages should be such that help the students to think creatively, communicate well with other students and the teacher, using the language of the subject. Chemistry has its own unique technical language, which if properly used, enables the individual to express his ideas and communicate effectively with others.

There are several models available for individuals to develop educational software packages on their own. Each of these models describes approaches to a variety of tasks or activities, which take place during the process. Form the literature reviewed, the researcher gained an insight into the input needed in designing and developing the educational software package for the teaching and learning of chemical bonding, used in the present study; and also the instrument for the quality rating of the software package.

In Nigeria, computer-aided instruction is more effective in improving students' achievement and interest in chemistry. The need for teachers to use computer-aided packages in teaching chemistry was pointed out, however available records did not show any effort to determine the effect of use of the educational software packages on students interest and achievement' in chemical bonding. This gap in knowledge regarding the effect of e-learning via educational software package on students' interest and achievement in chemical bonding necessitated this study. Therefore, there is the need to evaluate the effect of software package (CBISP) on students' interest and achievement in chemical bonding.

CHAPTER THREE

RESEARCH METHOD

This chapter presents a description of the procedure of the study. The description includes the research design; instrument for data collection; validation of the instrument; reliability of the instrument; method of data collection; and method of data analysis.

Research Design

In this study, both the instrumentation design (ID) and a two-factor pretest-posttest non-equivalent non-randomised quasi-experimental control group designs are used. Instrumentation is the study, development and manufacture of instruments for a specific purpose (http://www.thefreedictionary.com/instrumentation). The Dictionary explains further that instrumentation includes the design, development or manufacture of, and ***using*** the instruments needed for some implementation in science, medicine, technology or industry. Lyons and Seow (2000) noted that instrumentation design is concerned with a creative thinking process that revolves around making tools or instruments to meet a specific need, or to solve a specific problem. Instrumentation requires the possession of a sound knowledge of the process of transforming problem-solving ideas into reality.

The emphasis in instrumentation is on the realisation of an object, an instrument or tool that can be tested and evaluated to check whether the design really solves the problem that informed its development. The International Centre for Educational Evaluation (1982) cited in Agbir (2004) asserts that 'a study belongs to instrumentation research if it is aimed at developing new or modifying content, procedure , technology or instrument of educational practice. From the point of view of its definition and explanation, instrumentation involves ***process*** and ***product*** or end of the process. Both aspects of instrumentation are significant in understanding the design and why it was used in this study, where it was construed to mean any process that involves and results in designing, constructing, testing and using tangible products, objects, tools or instruments for specific purpose.

The design of the present study fits into the definition of instrumentation. Firstly, there was a specific purpose – execution of the job of teaching and learning of chemical bonding, for which there was need for an instrument (a tool and product of a process) for the specific purpose. In the context of this study, the instrument developed was the Chemical Bonding Instructional Software Package (CBISP). It was designed to meet the needs of teachers and students who find the concept of chemical bonding difficult in a teaching-learning process.

Nworgu (2006) refers to quasi-experimental design as one which 'random assignment of subjects to experiment and control groups is not possible. In this, intact or pre-existing groups are used.' The present study fits into the conventional definition of instrumentation and quasi-experimental designs. This is because

1. an instrument or tool, CBISP was developed and tested;
2. intact or pre-existing groups were used. In particular, different schools were used, some as experimental, the others as control groups.

It was at the stage of testing and evaluation of the software package that a two-factor pretest-posttest non-equivalent non-randomised quasi-experimental control group design was used. This is because existing or intact groups (classes) and two levels of treatment were involved. Non-equivalent factorial design proves most useful in situations where, constraints, subjects could not be randomly assigned to treatment (Campbell and Stanly, 1986). The constraint in this study had to do with school location and regulations. It was better to allow the students to remain in their existing natural setting, their usual classrooms, and under the guidance of their regular classroom teachers.

Symbolically, the design is

O_1 X O_2

O_1 ~X O_2

Where, O_1 = pretest observation

O_2 = posttest observation

X = the treatment

------ = an indication that the treatment and control groups used were not arrived at by random assignment of subjects to conditions.

The dependent variables of this study were students' achievement and interest in chemical bonding while the independent variables were the teaching methods namely, Instructional Software Package Method (ISPM) and the traditional lecture method (TLM).

Area of study

The area of study was Nsukka Education zone of Enugu state. Nsukka Education zone is made up of three local government areas, namely Igbo-Etiti, Nsukka and Uzo-Uwani. The zone has 58 secondary schools controlled by the same education authority – the State Post-primary Schools Management Board. The schools are distributed as follows: Igbo-Etiti: 16; Nsukka: 30; and Uzo-Uwani: 12. All the schools, except one, offer chemistry at the senior school certificate level. Therefore, only 57 of the 58 secondary schools were available for this study. The choice of the zone for this study was in consideration of the homogeneous nature of the schools in the zone. All the schools are under the same education authority. Besides, it was convenient for the researcher to effectively manage financial resources available for the study. The researcher had to visit all the schools involved in the study on regular basis throughout the study period, to monitor the activities of the cooperating classroom teachers, and hence ensure that they were in line with the agreed plans of the study.

Population for the study

The population consisted of 5,966 senior secondary class one (SS1) students studying chemistry in Nsukka Education zone of Enugu state of Nigeria during the 2012/2013 academic session. This figure was obtained from the Nsukka zone office of Enugu State Post-primary Schools Management Board. The choice of this grade of students was because chemical bonding, that is, the unit or concept for which the instructional software and the course of study were based is located in SS1 section of the NERDC curriculum for senior secondary school chemistry in use in Nigerian schools.

Sample and Sampling Techniques

The sample consisted of 311 SS1 students drawn from 9 senior secondary schools in Nsukka education zone of Enugu State, Nigeria, 5 of the schools made up of 3 urban-located schools and 2 rural-located schools constituted the experimental group; the control group consisted of 4 schools made up of 2 urban-located schools and 2 rural-located schools. For the experimental group, an additional urban school became necessary in order to have a sizable number of students close to that of the control group. There were 16 rural located schools and 41 urban located schools. Purposive sampling technique was used for selection of schools, based on the following criteria: availability of ICT facilities such as computer and overhead projectors; ability of teachers to perform basic operations using the afore mentioned ICT facilities; school location (urban and rural) and gender of students.

Instruments for Data Collection

Two instruments namely, Chemical Bonding Achievement Test (CBAT) and Students' Interest Scale on Chemical Bonding (SISCB) were used in this study.

Chemical Bonding Achievement Test (CBAT)

This instrument was used to assess the effect of the chemical bonding software package (CBESP) on the learning of students. The Chemical Bonding Achievements Test (CBAT) (Appendix C) is a 20 items multiple-choice test drawn from various chemical bonding units as recommend by the NERDC curriculum for SS1 chemistry (Appendix A2). The test blueprint for the construction of the Chemical Bonding Achievements Test (CBAT) is shown in Appendix A3. In the blueprint, the weighting of the content is as follows: Periodic table, 20%; Electronic configuration, 40%; and types of bonds, 40%. Process objectives: Recall, 40%; Comprehension, 40%; and Application, 20%. In making the blueprint for the test, the researcher was guided by Thorndike and Hagen's (1969) principle of using only those objectives that are assessable either wholly or in part by a paper and pencil test. The weighting of the content was based on the provisions of the curriculum content for teaching chemical bonding in SS1 classes. Initially, 27 items were developed by the researcher. Each item has four response options namely A, B, C and D, with only one option as the key while others are distracters.

Students' Interest Scale on Chemical Bonding (SISCB)

The second instrument called Students' Interest Scale on Chemical Bonding (SISCB) is a questionnaire developed by the researcher. The SISCB is a four point Likert-type scale, containing fourteen items, with four response options. The response options are Strongly Agree, Agree, Disagree and Strongly Disagree. On the scale, Strongly Agree = 4, Agree = 3, Disagree = 2 and Strongly Disagree = 1, for positive statements and were reversed for negative statements.

Validation of the Instruments

Two university chemical educators, one measurement and evaluation expert and six professional secondary school chemistry teachers (one of them a Chief Examiner in WAEC SSC Chemistry examination) face validated the CBAT. They were requested to

(i) assess the suitability of each topic as drawn to reflect the content of SS1 chemistry curriculum issued by the Nigeria Educational Research and Development Council (NERDC);

(ii) assess the language level and indicate whether the language was appropriate for the subject with respect to the use of technical terms;

(iii) comment generally on the suitability of the test items.

For face validity, the experts compared the developed instrument with the provisions of the test blueprint. The experts were also requested to make recommendations that may enrich and benefit the instrument. After face validation, only 20 questions were accepted for the CBAT while 7 were rejected and dropped.

The SISCB was face validated by one measurement and evaluation expert and two university chemical educators. The experts assessed the following:

(i) If the statements were clear, unambiguous and easy to interpret.

(ii) If the statements actually reflected solicited expression of interest.

(iii) If some of the statements overlapped.

The experts were requested to suggest changes that could be made to improve the SISCB. The comments of the experts guided and determined the modification that was made in the instruments before using them. For instance, the blueprint for the construction of the

CBAT was restructured such that the table for content now appears vertically while the levels appear horizontally. Also, the item for each level in the blueprint was specified.

Reliability of the Instruments

In order to determine the reliability of the instruments, a trial–test was carried out on SS1 students, using the final version of CBAT and SISCB. The students used for this trial test came from three institutions that were not involved in the actual research. The data obtained were used to calculate the reliability of CBAT and SISCB using the Kuder-Richardson Formula 20 and Cronbach alpha formula respectively. The reliability coefficient of CBAT and SISCB were 0.87 and 0.68 respectively. (See Appendix F and Appendix G). The Kuder-Richardson Formula 20 was used because responses to the test (CBAT) entailed right or wrong answers, that is, they are dichotomously scored. For the SISCB, Cronbach alpha formula was used because the responses to the items in the instruments are polytomously scored. In other words, the responses did not involve pass or fail (true or false) answers, rather rating was done according to response options given by the respondent.

Development of chemical bonding instructional materials

The following were instructional material developed and used in the study: Course of Study on Chemical Bonding (CSCB) and Chemical Bonding Instructional Software Package (CBISP).

Course of Study on Chemical Bonding *(CSCB)* : This course (Appendix A) is based on the content prescriptions of the NERDC (2009) chemistry curriculum for teaching and studying of chemical bonding in class one (SS1) of Nigerian senior secondary schools. At that level, chemical bonding is studied under the topic - Chemical Combination, in a broad theme: The Chemical World (Appendix 2).

The CSCB was used for teaching chemical bonding to the students. The CSCB consists of 10 lessons that adequately covered the NERDC curriculum content for the concept of chemical bonding. The content includes periodic table, electronic configuration, and types of bonds. These topics were broken down into 35 sub-topics , and in a form necessary for students to understand the concept of chemical bonding. The objectives of each of the 10 lessons were drawn, to reflect those stated in the NERDC curriculum. A total number of 30 objectives were stated for the 10 lessons that covered the 35 sub-topics. The topic: **Period Table**, had 5 sub-topics covered in one lesson , that is., 1/10 or 10 % of the total number of lessons on chemical bonding; **Electronic Configuration** had 15 sub-topics covered in 5 lessons, i.e., 5/10 or 50 % of the total number of lessons on chemical bonding; and **Types of Bonds** with a total number of 15 sub-topics covered in 4 lessons, i.e., 4/10 or 40 % of the total number of lessons on chemical bonding.

For objectives of the lessons, Periodic Table had 3 of the 30 objectives. i.e., 3/30 or 10 % of the number of objectives in all the lessons on chemical bonding; Electronic Configuration had 14 of the 30 objectives. i.e., 14/30 or 47 % of the number of objectives in all the lessons on chemical bonding; and Types of Bonds had 13 of the 30 objectives. i.e., 13/30 or 43 % of the number of objectives, in all the lessons on chemical bonding. The above were the criteria for percentage allotted to each lesson and objectives in the lessons. In preparing the blueprint for Course of Study on Chemical Bonding (CSCB) (Appendix A1), the researcher was guided by the school timetable, which stipulates the duration of a typical chemistry lesson and the number of times the subject is studied per week in the school.

Two university chemical educators, one measurement and evaluation expert and six professional secondary school chemistry teachers (one of them a Chief Examiner in WAEC SSC Chemistry examination) face validated the CSCB. The experts were requested to assess the course of study in respect of the following:

Content Information

If the content information was correct.

If the language, with regard to technical terms used was appropriate.

If the level of language used in communicating concepts was suitable for the grade of students for which the course was written.

1. ***Curriculum congruence***

   If the course work supports the curriculum.

2. ***Content presentation***

   If the pedagogical content was presented in such a way that learning will take place.

3. ***Lesson evaluation***

   If the questions and activities provided for evaluation of the lessons are suitable for that purpose.

The experts were also requested to make recommendations that may enrich and benefit the instrument. For quality assessment/ validity, the experts compared the CSCB with the provisions of the blueprint for course of study on chemical bonding (CSCB) (Appendix 1).

An instrument, Inventory for Course of Study on Chemical Bonding (ICSCB) (Appendix E) was developed and used to determine the reliability of the course of study. It consists of 8 criteria which centre on correctness of information presented in the course, appropriateness of language and use of technical terms, language level with regard to the age and grade of students, illustrations and tables, curriculum congruence, content presentation and lesson evaluation. The criteria are rated on a four-point likert-scale, ranging from 4-1; for Excellent = 4, Good =3, Fair =2, Poor =1. Nine professional chemistry teachers who were not involved in the actual study evaluated the CSCB using the ICSCB. The scores of these teachers were used to calculate the reliability coefficient of CSCB, For the CSCB, the reliability coefficient (α) = **0.63,** using Cronbach alpha method.

Chemical Bonding Instructional Software Package (CBISP)

The chemical bonding instructional software package (CBISP) is a computer software package that teaches specific skills and knowledge in chemical bonding to first year chemistry students in Senior Secondary schools. It presents instructional activities in ten lessons tailored to meet the needs of the learners in understanding the concept of chemical bonding, thus laying a strong foundation needed for further studies in chemistry. In the present study, teachers and students used the CBISP as an intervention tool to aid the teaching-learning process.

In creating the software package, the following processes were adopted:

(i) requirement specification, design and coding;

(ii) integration.

Requirement specification, design and coding: At this stage, all that was needed to design, create and animate electronic slides that run on computers were identified and recorded (Appendix B). The electronic slides are dynamic slides that automatically change after a set time. This involved designing of slides, inserting text and graphics and animations of slides and their objects.

Integration: This entails adding animation effects to slides. The following steps were taken:

a) *Transition effect*, using this option, the way one slide leaves the screen and another one appearing could be controlled.

b) *Custom animation,* this enables the user to control the appearance of various slide elements, which could be some text image, illustration, photographs, etc.

c) Adding voice to the slide presentation, saving and burning the presentation in a compact disk (CD) . This is the software package.

This process is an adaption of the Waterfall model of software development. The waterfall model (Waterfall model, 2012) of creating software is one that organises various developmental phases in a linear order that progresses, systematically from one phase to another in a downward fashion, like a waterfall. The developmental phases are: requirements, design, implementation, verification and maintenance.

Software Rating Scale (SRS)

The Software Rating Scale (SRS) (Appendix D) was constructed and used by the researcher for determining the reliability of the CBISP. It consists of 14 most important evaluation criteria used by educational software evaluation consortium (Bitter and Wighton, 1987). The 14 criteria centre on correctness of presentation; content presentation; integration into classroom use; ease of use; curriculum congruence; user control program; teacher documentation; colour, sound, graphic, and animation features; reliability; and content bias. The SRS is a 4-point Likert-scale. A minimum of 60% (2.4 of maximum marks of 4 or 100%) is the fixed benchmark level of quality acceptable for each of the evaluation criteria.

Four experts (2 instructional software package designers and 2 professional secondary school chemistry teachers) rated the CBISP, using the SRS. Data obtained with the SRS in the pilot study was used for calculating the reliability coefficient of the CBISP, based on Cronbach alpha method. A value of 0.81was obtained as the internal consistency of the CBISP.

Experimental procedures

The researcher trained regular chemistry teachers of the selected schools for experimental group for one week. The teachers received training (Appendix N) on how to use the CBISP for teaching. Thereafter, each of the teachers received a copy of the CBISP and those for control group were issued with the validated copy of CSCB to familiarise with. Before treatment commenced, the instruments, CBAT and SISCB were administered to the students, as pre-test and their score recorded.

The treatment for the study was teaching, using the Instructional Software Package Method (ISPM), and this lasted for five weeks. The ISPM involves guiding the students and making necessary explanation to the students as they learn, using the CBISP. The CBISP provides an interactive educational environment enriched with many images, animated clips, voice recordings and written words. For the control group, the traditional lecture method (TLM) was used. In this case, only the CSCB was used. The CSCB is a hard copy and has the same text materials and illustrations as in CBISP.

Three periods of 40 minutes each week were used for teaching of the students, following the usual school timetable as was peculiar to each school. The next day, immediately after the completion of treatment, the CBAT and SISCB were administered again to the students by the researcher as post-test and their scores were recorded. For this post-test, the various questions in CBAT were rearranged to eliminate the effect of familiarity with the items in the instruments.

Precautions and Control of Extraneous Variables

1. Teacher Variable

(i) To avoid interference of teacher personality, the same regular subject teacher taught the students. However, the teachers' teaching methods varied in line with the focus of the study. The lesson plan used in each school was the same one prepared by the researcher for the purpose of this study.

(ii) All the teachers received the same training, given by the researcher. The training lasted for one week, of four hours for each day of the week. The training programme for the teachers included getting used to

(a) activities to be performed by teachers and the students during the teaching-learning process;
(b) demonstration teaching by the teachers, using the lesson plan developed by the researcher for this study.

2. Initial Group Difference

The classes used in this study were intact classes and not randomly assigned. For this reason, the analysis of covariance (ANCOVA) was used to determine non-equivalence of these intact classes; the covariates are the pre-test and post-test scores.

Method of Data Collection

Before the experiment commenced, the CBAT and SISCB were administered as pre-test to the students in the schools. The scores obtained by the students in the pre-test were recorded and kept for use at the end of the experiment. At the end of the experiment, post-tests (CBAT) and (SISCB) were administered to the students. The scores of the post-tests were recorded differently.

Method of Data Analysis

Mean and standard deviation were used in answering the research questions. The hypotheses were tested, using analysis of covariance (ANCOVA) at 0.05 level of significance. The covariates are the pre-test and post-test scores.

CHAPTER FOUR

RESULTS

This chapter presents the results of the study organised in accordance with the research questions and hypotheses of the study. The research questions are answered, using means and standard deviation. The hypotheses are tested, using analysis of covariance (ANCOVA) at 0.05 level of significance.

Research Question 1

What is the effect of the use of Chemical Bonding Instructional Software Package (CBESP) on secondary school students' achievement in chemical bonding?

Table 7: Means and Standard Deviation of Students' Scores in Post-test CBAT (Teaching Methods x Achievement)

Experimental Conditions	Teaching Methods	No of Subjects (N)	Mean (X)	Standard Deviation (SD)
Experimental	Software (ISM)	162	9.3704	3.5067
Control	Trad. Lecture Method	149	8.4631	3.0124
Total		**311**	**8.9357**	**3.3053**

The data in Table 7 above indicates that the mean achievement score for the experimental group taught with software (CBISP) is 9.3704 while that of the control group taught using the traditional lecture method is 8.4631. From the difference in the means scores, it appears that subjects in the experimental group obtained higher scores than those in the control group in the chemical Bonding Achievement Test (CBAT).

In order to ascertain whether this observed difference is real or attributed to error variance, this result was subjected to inferential testing as hereunder shown.

Ho_1: There is no significant difference between the mean achievement scores of students taught chemical bonding using CBISP and those taught using lecture method.

The result in Table 8 shows that method as a main effect on students' achievement in chemical bonding is significant at 0.05 level. This is because its probability value of 0.000 is shown to be lower than the level of 0.05 at which it is being tested. This implies that method has statistically significant effect on students mean achievement in chemical bonding at 0.05 level.

Therefore, the null hypothesis, (Ho_1) of no significant difference between the mean achievement scores of students taught chemical bonding using CBISP and those taught using traditional lecture method is rejected at 0.05 level of confidence. Therefore, the earlier observed difference between the overall mean achievement score of students taught chemical bonding using CBISP and those taught using traditional lecture method as shown in Table 7 is a real difference, which is not attributed to error, associated with the study.

Table 8: Analysis of Covariance (ANCOVA) of students' overall achievement scores by gender and teaching method

Source of variation	Sum of squares	Df	Mean squares	F	Signifi-cance	Decision at 0.00 level
Pre-achievement	53.628	1	153.628	28.952	.000	S
Main effects	161.287	3	53.763	10.132	.000	S
Gender	17.151	1	17.151	3.232	0.73	NS
Location	22.502	1	22.502	4.241	0.040	S
Method	85.441	1	85.441	16.102	.000	S
2-way interaction	1202.698	3	400.899	75.551	.000	S
Gender x location	64.693	1	64.693	12.192	.001	S
Gender x method	386.535	1	386.535	72.844	.000	S
Location x method	384.042	1	384.042	72.374	.000	S
3-way interaction	5.970	1	5.970	1.092	.297	NS
Method x Gender x Location	5.970	1	5.970	1.092	.297	NS
Explained	1778.894	7	254.128	47.891	.000	S
Residual	1607. 820	303	5.306			
Total	**3392. 684**	**311**	**10.925**			

S = significant at 0.05 level; NS = Not significant at 0.05 level

Research question 2: What is the influence of students' gender on their achievement in chemical bonding?

Table 9 : Means and standard deviations of students' scores in post test CBAT (Gender x Achievement).

Gender	No of subjects	Mean	Standard Deviation
Male	174	8.0230	2.9679
Female	137	10.0949	3.3582
Total	**311**	**8.9367**	**3.3053**

The above data (Table 9) shows that the mean achievement score of male students is 8.0230 while that of the female students is 10.0949. It would appear from the difference in the mean scores that female students scored higher in the CBAT than the male students. In order to ascertain whether this observed difference is real or attributed to error variance, this result was subjected to inferential testing as hereunder shown.

Ho_2: Students' gender is not a significant factor of their mean achievement in chemical bonding.

The result in Table 8 shows that gender as a main effect on students' achievement in chemical bonding is not significant at 0.05. This is because its probability value of 0.73 is shown to be higher than the level of 0.05 at which it is being tested. Therefore, the null hypothesis, (Ho_2) of students' gender not being a significant factor of their mean achievement in chemical bonding is accepted at 0.05 level of confidence. This implies that the earlier observed difference between the overall mean achievement scores of female and male students as shown in Table 9 is not a real difference, but that which may be attributed to chance.

Research Question 3: What is the influence of school location on the students' achievement in chemical bonding?

Table 10 : Means and standard deviation of students' scores in post-test CBAT (School location x Achievement)

Location	No of subjects	Mean	Standard Deviation
Urban	128	8.7578	3.6409
Rural	183	9.0601	3.0530
Total	**311**	**8.9357**	**3.3053**

Table 10 shows that the mean achievement score of students' in rural location schools is 9.0601 while that of students in Urban location schools is 8.7578. From the difference in the mean achievement scores, it appears that students in rural location schools scored higher than their urban counterparts in CBAT did.

In order to ascertain whether this observed difference is real or attributed to error variance, this result was subjected to inferential testing as hereunder shown.

H_{O3}: School location does not significantly influence students' mean achievement in chemical bonding.

The result in Table 8 shows that location, as a main effect on students' achievement in chemical bonding is significant. This is because its probability value of 0.00 is shown to be lower than the level of 0.05 at which it is being tested. Therefore, the null hypothesis, (Ho_3) of School location not having significant influence on students' mean achievement score in chemical bonding is rejected at 0.05 level of confidence. This implies that the earlier observed difference between the overall mean achievement scores of students' in rural location schools and those of students in Urban location schools, as shown in Table 9 is a real difference, which is not attributed to error associated with the study.

Research Question 4: What is the effect of CBISP on students' interest in chemical bonding?

Table 11: Means and Standard Deviation of Students in post interest score (Teaching Method x Interest)

Experimental Conditions	Teaching Methods	Number of Subjects	Mean	Standard Deviation
Experimental	ISPM	162	42.5864	5.0151
Control	TLM	149	14.3490	1.4185
Total		**311**	**29.0579**	**14.6169**

Table 11 shows that the mean interest score is 42.5864 for the experimental group taught with CBISP while that of the control group taught using traditional lecture method is 14.3490. From the difference in the mean scores, it appears that students in the experimental group scored higher than those in the control group did on the Interest scale rating.

Table 12: **Analysis of Covariance (ANCOVA) of students' overall interest scores by the Gender, Location and Teaching Method**

Source of Variation levels	Sum of squares	Df	Mean squares	F	Signifi-cance	Decision at 0.00
Pre-interest	1.583	1	1.583	.117	.733	NS
Main effects	48570.027	3	16190.009	1192.443	.000	S
Gender	40.510	1	40.510	2.984	.085	NS
Location	15.572	1	15.572	1.147	.285	NS
Method	37971.690	1	37971.690	2796.729	.000	S
2-way interactions	133.149	3	44.383	3.269	.022	NS
Gender x location	4.973	1	4.973	.366	545	NS
Gender x method	75.141	1	75.141	5.534	.019	S
Location x method	3.877	1	3.877	.286	.593	NS
3-way interactions	.326	1	326	037	.848	NS
Method x Gender						
x Location	.326	1	. 326	.037	.848	NS
Explained	6211.9.073	7	8874.153	653.608	.000	S
Residual	411.885	303	13.577			
Total	**66233.284**	**311**	**213.655**			

S = significant at 0.05 level; NS = Not significant at 0.05 level

In order to ascertain whether this observed difference is real or attributed to error variance, this result was subjected to inferential testing as hereunder shown.

Ho_4: There is no significant difference in the students' interest in chemical bonding between those taught chemical bonding using CBISP and those taught using lecture method.

Table 12 is analysis of covariance (ANCOVA) of students' overall interest scores by gender, location and teaching method. The results in Table 12 show that method as a main effect on students' interest in chemical bonding is significant. This is because its probability value of 0.00 is shown to be lower than the level of 0.05 at which it is being tested. Therefore, the null hypothesis, (Ho_4) of no significant difference in the students' interest in chemical bonding between those taught chemical bonding using CBISP and those taught using lecture method is rejected at 0.05 level of confidence. This implies that the earlier observed difference between the overall mean interest scores of students taught chemical bonding using CBESP and those taught using lecture method, as shown in Table 11 is a real difference, which is not attributed to error associated with the study.

Research Questions 5

What is the effect of students' gender on their interest in chemical bonding?

Table 13: **Means and standard deviations of students in post-interest scores (gender x interest).**

Gender	No of Subjects	Mean	Standard Deviation
Male	174	28.6609	15.2991
Female	137	29.5620	13.7407
Total	**311**	**29.0579**	**14.6169**

Table 13 shows that the mean interest score of male students is 28.6601 while that of the female students is 29.5620. It appears from the difference in the mean scores that female students scored higher in the interest rating scale than the male students did.

In order to ascertain whether this observed difference is real or attributed to error variance, this result was subjected to inferential testing as hereunder shown.

Ho_5: The influence of gender on students' mean interest rating chemical bonding is not significant.

The result in Table 12 however shows that gender as a main effect on students' interest in chemical bonding is not significant. This is because its probability value of 0.09 is shown to be higher than the level of 0.05 at which it is being tested. Therefore, the null hypothesis, (Ho_5) of no significance is accepted at 0.05 level of confidence. This implies that the earlier observed difference between the overall mean interest scores of female and male students as shown in Table 13 is not a real difference, but that which is attributed to chance.

Research Question 6

What is the effect of students' school location on their interest in chemical bonding?

Table 14: Means and standard deviation of students in post interest (School location x interest)

Location	Number of Students	Mean	Standard Deviation
Urban	128	31.7188	14.1025
Rural	183	27.1967	14.7199
Total	**311**	**29.0579**	**14.6169**

Table 14 shows that the mean interest score of student in urban schools is 31.7188 while that of students from rural schools is 27.1967. From the difference in the mean scores, it appears that students in urban schools scored higher in the interest rating scale than the student from rural schools did. In order to ascertain whether this observed difference is real or attributed to error variance, this result was subjected to inferential testing as hereunder shown.

Ho_6: The influence of school location on students' mean interest rating in chemical bonding is not significant.

The result in Table 12 shows that location as a main effect on students' interest in chemical bonding is not significant. This is because its probability value of 0.29 is shown to be higher than the level of 0.05 at which it is being tested. Therefore, the null hypothesis, (Ho_6) of no significant difference is accepted at 0.05 level of significance. This implies that the earlier observed difference between the overall mean interest scores of students in rural location schools and those students in Urban location schools, as shown in Table 14 is not a real difference, but that which may be attributed to chance. This implies that location has no statistically significant effect on students' mean interest in chemical bonding at 0.05 level.

Research Question 7:

What is the interaction effect of gender and school location on students' mean achievement in chemical bonding?

In order to ascertain the interaction effect of gender and location on students' mean achievement in chemical bonding, data in Tables 8 and 10 were examined against the backdrop of the hypothesis:

Ho_7 The interaction effect of gender and location on students' mean achievement in chemical bonding is not significant.

Results in Table 8 show that the probability value of 0.001 of the interaction effect of gender and school location on achievement in chemical bonding is lower than the level of 0.05 at which it is being tested; while Table 10 shows means and standard deviation of students in post achievement. The null hypothesis (Ho_7) is rejected at 0.05 level of significance. This implies that the interaction of gender and school location on students' mean achievement score in chemical bonding is significant. Therefore, the earlier observed difference between the overall mean achievement of urban and rural school students as shown in Table 10 is a real difference, not attributed to chance associated with the study.

Research question 8: What is the interaction effect of gender and method of teaching on students' mean achievement in chemical bonding?

In order to ascertain the interaction effect of method of teaching and gender on students' mean achievement in chemical bonding, data in Tables 8 and 9 were examined against the backdrop of the hypothesis:

Ho_8 The interaction effect of gender and method of teaching on students' mean achievement in chemical bonding is not significant.

Results in Table 8 show that the probability value of 0 .000 of the interaction effect of gender and method on achievement in chemical bonding is lower than the level of 0.05 at which it is being tested while Table 9 shows means and standard deviations of students in post-achievement scores. The null hypothesis (Ho_8) is rejected. This implies that the earlier observed interaction effect (in Table 9) between students taught using CBISP and those taught using traditional lecture method is actually a real effect and not that attributed to chance associated with the study. This implies that the effect of interaction of gender and teaching methods on students' mean achievement in chemical bonding is significant at 0.05 level.

Research question 9:

What is the interaction effect of location and method of teaching (CBISP and lecture) on students' achievement in chemical bonding?

In order to ascertain the interaction effect of location and method of teaching on students' mean achievement in chemical bonding, data in Tables 8 and 10 were examined against the backdrop of the hypothesis:

Ho_9 The interaction effect of location and method of teaching (CBISP and lecture) on students' mean achievement in chemical bonding is not significant.

The result in Table 8 shows that the probability value (0.000) of interaction effect of location and teaching methods is lower than the level of 0.05 at which it is being tested while Table 10 shows means and standard deviation of students score in post achievement. The null hypothesis, (Ho_9) is rejected at 0.05 level of confidence. This implies that the earlier observed difference between the overall mean achievement scores of students' in rural location schools and those of students in Urban location schools, as shown in Table 10 is a real difference that is not associated with chance in the study. Therefore, the interaction of location and teaching methods as a main effect on students' interest in chemical bonding is significant at 0.05 level.

Research Question 10.

What is the interaction effect of gender and school location on students' mean interest rating in chemical bonding?

In order to ascertain the interaction effect of gender and location on students' mean interest rating in chemical bonding, data in Tables 13 and 14 were examined against the backdrop of the hypothesis:

Ho_{10} The interaction effect of location and gender on students' mean interest rating in chemical bonding is not significant.

Results in Table 12 show that the probability value of 0.55 at which the interaction effect of gender and school location on interest in chemical bonding is higher than the level of 0.05 at which it is being tested, while Table 14 shows means and standard deviation of students in post interest. The null hypothesis ($H0_{10}$) is accepted at 0.05 level of significance. This implies that the interaction of gender and school location on students' mean interest score in chemistry is not significant. Therefore, the earlier observed difference between the overall mean interest rating (score) of urban and rural school students as shown in Table 14 is not a real difference, but that which is attributed to chance associated with the study.

Research Question 11.

What is the interaction effect of gender and teaching method on students' interest in chemical bonding?

In order to ascertain the interaction effect of gender and method of teaching on students' mean interest rating in chemical bonding, data in Tables 12 and 13 were examined against the backdrop of the hypothesis:

Ho_{11} The interaction effect of gender and method of teaching on students' mean interest rating in chemical bonding is not significant.

Results in Table 12 show that the probability value of 0.019 of the interaction effect of gender and method on interest in chemical bonding is lower than the level of 0.05 at which it is being tested while Table 13 shows means and standard deviations of students in post-interest scores (gender x interest). The null hypothesis (Ho_{11}) is rejected. This implies that the earlier observed interaction effect (in Table 13) between students taught using CBISP and those taught using traditional lecture method is actually a real effect and not that which may be attributed to chance. This implies that the effect of interaction of gender and teaching methods on students' mean interest score in chemical bonding is significant at 0.05 level.

Research Question 12. What is the interaction effect of school location and teaching methods on students' interest in chemical bonding?

In order to ascertain the interaction effect of location and method of teaching on students' mean interest rating in chemical bonding, data in Tables 12 and 14 were examined against the backdrop of the hypothesis:

Ho_{12} The interaction effect of method of teaching (CBISP and lecture) and location on students' mean interest rating in chemical bonding is not significant.

The result in Table 12 shows the probability value (0.593) of interaction effect of method and location is higher than the level of 0.05 at which it is being tested while Table 14 shows means and standard deviation of students scores in post interest (School location x Interest). The null hypothesis, (Ho_{12}) is accepted at 0.05 level of significance. This implies that the earlier observed difference between the overall mean interest scores of students' in rural location schools and those of students in Urban location schools, as shown in Table 14 is not a real difference but that which could be associated with chance in the study. Therefore, the interaction of location and teaching methods as a main effect on students' interest in chemical bonding is not significant at 0.05 level.

Ho_{13} The interaction effect of teaching method, students' location and gender on their mean achievement in chemical bonding is not significant.

In order to ascertain the interaction effect of teaching method, students' location and gender on their mean achievement in chemical bonding, Table 8 which is analysis of covariance (ANCOVA) of students' overall achievement scores by gender and teaching method was examined. The result in Table 8 shows that the probability value (0.297) of the interaction effect of teaching method, students' location and gender is higher than the level of 0.05 at which it is being tested. The null hypothesis (Ho_{13}) is accepted at 0.05 level of significance. Therefore, the interaction effect of teaching method, students' location and gender on their mean achievement in chemical bonding is not significant at 0.05 level.

Ho_{14} The interaction effect of teaching method, students' location and gender on their mean interest rating in chemical bonding is not significant.

An examination of Table 12, which is analysis of covariance (ANCOVA) of students' overall interest scores by the Gender, Location and Teaching Method was carried out in order to ascertain the interaction effect of teaching method, students' location and gender on their mean interest rating in chemical bonding. The result in Table 12 shows the probability value (0.848) of interaction effect of teaching method, students' location and gender is higher than the level of 0.05 at which it is being tested. The null hypothesis ($H0_{14}$) is accepted at 0.05 level of significance. Therefore, the interaction effect of teaching method, students' location and gender on their mean interest rating in chemical bonding is not significant.

Summary of Finding

1. Method of teaching has statistically significant effect on students mean achievement in chemical bonding.
2. Gender has no statistically significant effect on students' achievement in chemical bonding.
3. School location has statistically significant effect on students' mean achievement in chemistry.
4. Method has statistically significant effect on students' interest in chemical bonding.
5. Gender has no statistically significant effect on students' interest in chemical bonding.

6. School location has no statistically significant effect on students' mean interest in chemical bonding.
7. The interaction effect of gender and location on students' achievement in chemical bonding is significant.
8. The interaction effect of gender and method on students' achievement in chemical bonding is significant.
9. The interaction effect of location and teaching method on students' achievement in chemical bonding is significant.
10. The interaction effect of gender and location on students' interest in chemical bonding is not significant.
11. The interaction effect of gender and teaching method on students' interest in chemical bonding is significant.
12. The interaction effect of school location and teaching methods on students' interest in chemistry is not significant.
13. The interaction effect of gender, location and method on students' achievement in chemical bonding is not significant.
14. The interaction effect of gender, location and teaching methods on students' interest in chemistry is not significant.

CHAPTER FIVE

DISCUSSION, CONCLUSION AND SUMMARY

This chapter presents the discussion of the findings, conclusion reached from the findings, implications of the findings of the study, recommendations, suggestions for further studies and summary of the study.

Discussion of the findings of the study

The discussion is organised under the following sub-headings:

- Effect of chemical bonding educational software package on students' achievement in chemical bonding;
- Influence of gender on students' achievement in chemical bonding;
- Influence of interaction of gender and method on students achievement in chemical bonding;
- Effect of school location on students' achievement in chemical bonding;
- Influence of interaction effect of location and method on students' achievement in chemical bonding;
- Effect of chemical bonding instructional software package on students' interest in chemical bonding;
- Effect of gender on students' interest in chemical bonding;
- Influence of location on students' interest in chemical bonding;
- Influence of interaction of gender and method on students interest in chemical bonding.

Effect of Chemical Bonding Instructional Software Package on Students' Achievement in Chemical Bonding

Difference in the mean achievement scores of the two groups of students (the experimental group and the control group) is indicated in Table 7. The experimental group was taught using Educational Software Package Method (ESM) while the control group was taught using the traditional lecture method (TLM). The mean achievement score that resulted from the use of

Educational Software Package (ESM) exceeded that of the traditional lecture method. The difference in the mean achievement scores is indicative that teaching methods have positive effect on achievement in chemical bonding.

Results in Table 8 further buttresses and confirms the data in Table 7 by showing statistically significant effect of teaching methods on students achievement in chemical bonding. The observed probability value of 0.000, which was significant at 0.05 level of confidence, gives credence to the result. This implies that the difference in efficacy of the two teaching methods, as regards students' academic achievement in chemical bonding, is a reality. Therefore, students' academic achievement in chemical bonding varies with teaching methods. The above result shows that students' achievement in chemical bonding is better when taught using ISPM, than when taught using traditional lecture method. This finding therefore suggests that use of educational software package method is more efficacious than the lecture method.

This finding is in agreement with some previous research finding by Ifeakor (2005) and Adeniyi (1997), which respectively found that students taught using computer-aided educational software packages achieved more than students taught without computer aided instruction in chemistry and physics respectively did. However, this finding is not in agreement with findings of HU (2007) and Jegede, Okebukola and Ajewole (1992).

Hu (2007) reported that here was no difference in academic achievement between students who used educational software programmes for mathematics and reading and those who did not while Jegede, Okebukola and Ajewole (1992) found that there was no significant difference between the achievement profiles of students taught biology with and those taught without computer.

In spite of the inconsistency and controversy of above previous research findings, it is clear from the findings of this present study that ISPM is more efficacious than and superior to TLM in enhancing students' achievement in chemical bonding. Perhaps, this is because the CBISP allows students to work privately at their own pace without undue pressure or embarrassment from any quarters in case of any mistake in the course of the teaching-learning process.

Influence of gender on students' achievement in Chemical Bonding

The result of this study also shows that gender, as a main effect has no significant effect on students' achievement in chemical bonding. As shown in Table 9, female students had higher overall mean score of 10.09 as against the male students' overall mean score of 8.02 in Chemical Bonding Achievement Test (CBAT). This result was subjected to inferential testing, against the backdrop of the results in Table 8 where gender, as a main effect, showed a higher probability value of 0.73 at which this main effect is shown not significant, than the level of 0.05 at which it was tested. This implies that gender is not a significant factor in students' achievement in chemical bonding. This finding however disagrees with Trigwell (1990), but agrees with Inyang and Jegede (1991), and Erinosho (1994) reported in Adesoji and Babatunde (2008).

Trigwell (1990) found that male students were superior over female students in problem-solving and achievement in chemistry while Inyang and Jegede (1991) reported that gender has no effect on students' achievement in science.

Erinosho (1994) cited in Adesoji and Babatunde (2008) reported that the difference between the mean achievement scores of female and male students was not statistically significant in chemistry. Also, Agbir (2004) found that gender was not a significant factor in the overall mean achievement rating of students in practical skills on acid-base titration. Similarly, Ssempala (2004) asserted that there were no statistically significant difference between girls and boys in their ability to manipulate apparatus/equipment, take observation report/record results correctly, and compute/interpret/archive results during chemistry practical. The report further showed that girls performed slightly better than boys did overall.

But contrary to the above findings, Ahiakwo (1988) showed that girls performed better than boys and that the difference between their mean achievement score was significant beyond $P < 0.001$ and concluded that there is gender difference in achievement in chemistry process skill test. Ifeakor (2005) showed a significant gender-related difference in students' cognitive achievement in favour of male students over their female counterparts. Also, Ariyo and Ugodulunwa (2007) showed that gender of students was a significant factor in their overall performance on both chemistry and Science General Aptitude Test (SGAT), where the mean achievement of females exceeded that of males.

Three classes of results regarding gender-related differences in achievement in chemistry and science generally can be distinguished from these studies mentioned above, including the present one. The first is one in which there is significant difference in favour of female students (Ahiakwo, 1988); the second class is that in which gender related impact favours the male (Trigwell, 1990; Ifeakor, 2005; Ariyo and Ugodulunwa, 2007); the third class is that in which there is no significant difference.

In the present study, it has been shown that female students' overall mean achievement was higher than that of the male students even though statistically, gender was shown not to be a significant factor in students' achievement in chemical bonding.

Influence of interaction of gender and method on students achievement in Chemical Bonding

Results in Table 8 confirm that gender and method (ISPM) interaction has statistically significant effect on students mean achievement in chemical bonding. The observed probability value of 0.00 that was significant at 0.05 level of significance affirms this result. This is in agreement with Ifeakor (2005), which showed that the interaction effect due to teaching method and gender was significant. This perhaps explains the reason for the high overall mean achievement score (10.09) obtained by the female students against that (8.02) obtained by male students shown in Table 9.

This may have resulted from the students' manipulation of the computer in carrying out practical activities involved in the use of CBISP in the Teaching-learning process. Ssempala (2005) showed that in chemistry practical/skills that involved manipulation of apparatus/equipment, female students performed slightly better than boys did overall. This appears to be the case in the present study, the assumption here is that in using the CBISP, girls may have performed better than the boys in computer manipulation skills, which may have aided them in performing better than the boys, in the achievement test. The present study has shown that if appropriate methods that appeal to female students are used in teaching them, female students are likely to perform better than their male counterparts. Therefore, ISPM which has aided the female students to perform better in chemical bonding should be helpful in removing gender-related differences in secondary school students' performance in aspects of chemistry, especially chemical bonding.

Influence of School Location on Students' Achievement in Chemical Bonding

This study showed that students' mean achievement score in chemical bonding of students in rural location schools are higher than that of their urban location school counterparts in CBAT. Results in Table 8 confirm this finding, and show that location, as a main effect on students' achievement in chemical bonding is statistically significant. This implies that rural students achieved more than their urban counterparts did.

This is not in agreement with Agbir (2004) which showed that rural students performed better on practical skills in chemistry than their urban counterparts did; however, statistically it was shown in the same study that location was not a significant factor in the students' mean achievement in chemistry practical skills. Similarly, Ezeh (1998) showed that students' achievement in integrated science is not influenced by the difference in their physical environment and that there is no statistically significant difference in students' achievement in integrated science between urban and rural location of their schools (P. 204). But, Onah (2011) reported a significant difference in students' achievement with respect to school location. It was shown that location had a statistically significant different influence on the students' achievement in agricultural science, where students in urban schools had a higher mean achievement score than students in rural schools.

The result of this present study contradicts Jegede (1984), with regard to the influence of school location on students' academic achievement. Jegede (1984) showed that there was no statistically significant difference between the achievement of urban and rural students in physics, although the mean achievement scores of urban school students were higher than those of the rural schools. The present has shown that with ISPM, rural students achieved more than their urban counterparts did. This implies that ISPM should be of great assistance in reducing location-related differences in students' performance in aspects of ,chemistry especially chemical bonding.

Influence of Interaction effect of Location and Method on Students' Achievement in Chemical bonding

As shown in the present study, school location and method interaction was significant; rural students achieved more than urban students did in chemical bonding. The expectation has always been that localities that have different socio-cultural, economic and physical conditions would provide different learning experiences and stimulations to students, which invariably would affect their achievement. In this regard, one would have expected urban students who enjoyed certain basic amenities such as regular electricity, better equipped schools than their rural counterparts, to do better. But the reverse is the case in this study and presents a case for further investigation.

Effect of Chemical Bonding Instructional Software Package on Students' Interest in Chemical bonding

Results of this study showed that the experimental group of students taught using the CBISP scored higher than students taught using traditional lecture method on the interest rating scale. This is in agreement with Ifeakor (2005) and Olikeze (1999) who found in their respective studies that students taught using computer assisted instruction method showed more interest in chemistry and biology respectively. This implies that method of teaching, and in this case, ISPM has significant effect on the interest rating of the students, as affirmed in Table 11 of this study.

Certain factors are known to affect students' interest. These include relevance of the study material to the students' learning needs and aspiration. In this regard, students showed interest not only in the subject matter for what they would gain from it, with regard to the role it will play in the realisation of their future career, but also in the software package itself that helped them in learning the subject. The software provided activities and feedback that helped the students in the teaching-learning process. The activities in the CBISP are such that they aroused and sustained the students' interest both in chemical bonding and the package itself. Besides, the CBISP was tailored to the needs and level of the students, with regard to the provisions and recommendations of the chemistry curriculum in use in their schools.

Effect of Gender on students' Interest in Chemical bonding

In this study, gender was found to have no statistically significant effect on students' interest in chemical bonding. Female students' mean interest in chemistry rated 29.56 on the scale as against male students' mean rating of 28.66; and the difference in the two interest ratings (scores) was shown not to be statistically significant. This finding is not in agreement with Ifeakor (1999) and Olikeze (1999), who reported respectively, that gender has statistically significant effect on students' interest in chemistry and biology respectively. The result of the present study agrees however with Ifeakor (2005) in which it was shown that gender has no significant influence on students' interest in chemistry, and disagrees with Ogbonna (2003), which showed that gender is a significant factor in determining the interest of male and female students.

Explanation for more interest shown by female students in chemical bonding, as observed in this study; and perhaps as may be found in other science subjects in recent times, may be that boys are more interested in business studies-related courses, such as economics. Indeed, some of the boys involved in this study told the researcher that although they like the CBISP mode of teaching chemical bonding, they are more interested in business or law. They opined that business people make more money than those who studied science subjects.

Influence of Location on Students' Interest in Chemical bonding

In this study, it was found that location has no statistically significant effect on students' mean interest in chemical bonding. However, students in urban schools scored higher on the interest rating scale than students from rural schools. This finding agrees with Agbir (2004) in which it was shown that location of school was not a significant factor in the man interest rating of students in chemistry practical skills on acid-base titration. Interest is a trait that could be aroused, developed, sustained, and expressed. It would appear that the novelty of CBISP mode of presenting chemical bonding aroused more interest in the urban students than it did in their urban counterparts. The extent of arousal of interest in the students appeared to be what was expressed by the students in their scores. It is usually expected that urban students, many of who are used to electronic gadgets and the computer in particular would score higher on the interest scale than the rural students. This was the case in this result.

Influence of interaction of gender and method on students' interest in Chemical Bonding

The interaction of gender and method on students' interest rating was found in this study to be statistically significant. This implies that the interplay of gender and mode of presenting the subject matter determines largely the overall mean interest rating of students in chemical bonding. This result is contrary to that of Ogbonna (2003) in which there was no significant interaction effect between method and gender in mathematics; but in agreement with Ozofor (2001) which showed that the interaction effect of gender and method on students' interest on probability and statistics was statistically significant. It agrees also with Negedu (2008) assertion that gender and method interaction is significant and engenders more interest in females than males in integrated science.

The observed probability value in the present study of 0.019, which was significant at 0.05 level of confidence, confirms that the high overall mean interest rate (29.56) obtained by the female students against that (28.66) obtained by male students is real; and may have resulted from the students' manipulation of the computer in carrying out practical activities involved in the use of CBISP in the teaching-learning process. The assumption here is that in using the CBISP, girls may have performed better than the boys in computer manipulation skills, which may have aided them in performing better than the boys did on the interest rating scale. This assumption is supported by Ssempala (2005), who showed that no statistically significant difference existed between girls and boys in their ability to manipulate apparatus/equipment: in chemistry practical/skills but asserted that 'although girls performed slightly better than boys overall".

Conclusions Reached From the Findings of the Study

This study set out to develop and validate a software package for teaching chemical bonding in secondary schools. The study produced chemical bonding instructional software package (CBISP), and tested the effect of the use of the software package on students' interest and achievement in chemical bonding. The study has shown that CBISP has significant effect on students' achievement and interest in chemical bonding. The study showed that Instructional Software Package Method (ISPM) was more effective and efficacious than the traditional lecture method in bringing about more students' achievement and interest in chemical bonding.

The influence of gender on achievement in chemical bonding was not significant. However, female students appeared to be superior to male students in chemical bonding. Similarly, gender had no significant influence on the interest of students in chemical bonding. Female students however, scored higher on the chemical bonding interest scale than their male counterparts did.

School location was significant on students' achievement, but not on students' interest in chemical bonding. In achievement test, rural students scored higher than urban students did; and on interest rating, urban students scored higher than rural students did.

The interaction effect of gender and location on interest was not significant, whereas the interaction effect of gender and method (CBISP) was significant. Female students taught chemical bonding using CBISP performed better than male students did, using the same method, on both interest rating scale and achievement test. In addition, the interaction effect of location and method on achievement was not significant. This means that the relative efficacy of CBISP on students' interest across the locations was not consistent. Therefore, rural students taught with CBISP performed better than their urban counterparts did.

Educational Implications of the Findings

The outcome of this study has a number of educational implications for students, teachers, teacher-training institutions and the ministries of education. These implications are discussed as follows.

The development of both the CBISP and the instrument for its validation, quality evaluation and grading, provides a guide for teachers to be able to construct their own educational software packages and for the validation, quality evaluation and grading of educational software packages by subject experts, teachers, and curriculum developers. It implies that teachers, on their own, could develop software packages for teaching specific concepts to their students. Therefore, teacher-training institutions should infuse more training programmes or courses on ICT skills for their student-teachers who on graduation, should be able to fashion out their own educational software packages.

The evaluative aspect of the present study provides a feedback on the relative efficacy of teacher-made educational software packages. This provides a premise on which teachers of chemistry could rely upon, to develop educational software packages in an effort to improve and facilitate teaching-learning processes in Chemistry, especially with regard to the teaching of abstract and difficult concepts such as chemical bonding. This way, the problem of scarcity of relevant educational software packages for the education system could be addressed. The hope for sustainable supply of relevant educational software packages and the derivation of maximum benefits thereof will be enkindled and kept alive.

The study shows that CBISP engendered more interest in students, especially female students who performed better than their male counterparts on CBAT did. It implies that the adoption of CBISP as a mode of instruction is most appropriate in bringing about reduction in gender-related differences in both students' achievement and interest in chemical bonding and hence Chemistry.

Recommendations of the study

The following recommendations are made because of the implications of the results obtained in this study.

1. Since CBISP has been found to be effective and efficacious in improving the quality of both achievement and interest of students in chemical bonding, teachers of chemistry should be encouraged to use more of ISPM in teaching chemical bonding . In so doing, both the achievement and interest of students in chemistry could be enhanced.

2. Since gender is not a significant factor in students' achievement in chemical bonding, emphasis therefore should be placed on teaching methods, rather than on the students' gender. This is very important since every student is likely to gain maximally or to the same degree from a particular method.

3. Students' high mean achievement and interest scores in chemical bonding, resulting from the use of CBISP in teaching them, give credence to believe and assert that teachers on their own could fashion out educational software packages for teaching abstract concepts in Chemistry; and perhaps in other science subjects if they are equipped with relevant ICT knowledge and skills required to construct computer educational software packages. Therefore, the curriculum for teacher-training programmes in Nigerian teacher-training institutions and faculties could be reformed, and enriched with appropriate ICT courses that will enable teachers develop and use their own-made computer educational software packages, to make their teaching effective to the benefit of the learners.

4. The framework and procedure adopted in the development of the CBISP could serve as a model for training and retraining teachers in our education system. In this regard, the Department of Science Education, University of Nigeria, Nsukka where this study was carried out could champion and propagate this idea. It therefore recommends that the Department could partner with the various Ministries of Education, Science and Technology and relevant organisations such as Science Teachers' Association of Nigeria (STAN), Curriculum Organisation of Nigeria (CON) and Nigerian Educational Research and Development Council (NERDC) in organising workshops and seminars to train science teachers on the development and usage of teacher- made instructional software packages.

5. Since CBISP requires that both the teachers and students should be proficient in the use of ICT facilities like projectors, especially computers, the effort in encouraging e-learning and computer literacy in the school system should be intensified.

6. Government and other stakeholders in the school system, who can afford to do so, should equip schools with ICT facilities; especially computers to enable students use educational software packages easily.

7. All schools in Nigeria should be connected to the National grid to ensure supply of electricity at cheaper rate for without it, the use of computers in schools may become a mirage, as dependency on portable electricity generators to power the computers is very expensive and risky. Chances of explosion and fire while using the generators are there. Besides, they create a noisy and non-conducive atmosphere for learning as smoke and fume from the exhaust of the generators filter into the classrooms.

8. The CBISP could be patented and developed further, to become a source of revenue for both the researcher and this university. This is necessary in view of the present encouragement given to universities to increase and strengthen the source of their internally generated fund for use of the institutions.

Limitations of the Study

1. Some intervening variables in the quasi-experimental research such as the qualification and years of teaching experience of teachers may have affected the result of the study. Although the regular teachers of these intact groups were

used, the difference in both qualifications and teaching experience that existed amongst the teachers could, and may have affected the validity of the result.

2. The limited number of schools that had functional computers and other ICT facilities made it difficult for the researcher to use more schools. Besides, schools used were school either connected to the national grid or had standby electricity generator. Even where some of the schools had standby electricity generator, there were periods the researcher had to supply and fuel the generator to be used in the study. This made a cut down on the length of period the students had to use the computer, at least for revision purposes inevitable. This too, may have affected the result of the study.

3. The concept: 'Chemical Bonding' studied in this research is only one unit of related concepts in the topic: 'Chemical Combination' under the theme: 'The Chemical World' in the chemistry curriculum for SS1 students; the use of only one unit and SS1 students cannot be said to be enough and sufficient criteria to generalise the findings of this research.

4. Since the result is based on the sample drawn from a limited population in a particular geographical location and education zone in Enugu state, its generalisation is therefore limited, and therefore cannot be compared with another result that may be obtained from a similar research that uses a larger population involving the whole state or Nigeria as a whole.

Suggestion for Further Studies

A number of areas of interest for further studies emerged from the findings of this research. Based on this, the following suggestions are made:

1. Replicate this study, using a larger population and a wider geographical area, where possible, the entire Enugu State or another state in Nigeria.
2. Investigate and ascertain teachers' attitude to the use of self-made computer educational software packages in facilitating the teaching-learning process in a classroom.
3. Investigate and ascertain underlying factors that influenced rural students to perform better on the interest scale than their urban counterparts did, when both groups of students were exposed to the same educational software package method (ISPM) of teaching chemical bonding.
4. Investigate and ascertain the degree of teachers' interest in the use of CBISP. This is particularly important because in Nigeria, Computer Assisted Instruction (CAI) is receiving greater attention in curriculum design and pedagogy. It is necessary that teachers' interest towards particular educational software packages be investigated, since interest in and attitude towards the use of software

packages will of necessity determine their usage or otherwise in teaching and learning activities by both the teachers and their students. It is likely that teachers' interest in and attitude to the use of educational software packages may evoke similar reactions in their students.

Summary of the Study

Achievement in chemistry underlies the development of chemical industries associated with developed nations. Studies carried out in Nigeria indicate secondary school students' under achievement in chemistry. This is worrisome and could be blamed on ineffectiveness of traditional teaching method used in communicating chemical concepts to students. Researchers and curriculum developers recommend a new pedagogic approach that uses computer and other ICT facilities, as an intervention teaching strategy to improve achievement in the subject amongst secondary school students. The acceptance of this new pedagogic approach that uses computer as a vital instrument for teaching and learning in the 21st century implies that relevant educational software packages for specific lessons need to be developed.

Research reports indicate scarcity of these relevant software packages for Nigerian education system. Consequently, this research set out to develop a chemical educational software package for the teaching of chemical bonding, a concept that is found difficult by both students and teachers. Teachers find it difficult to teach the concept while students find it difficult to understand it. Because of its abstract nature and the pedagogic approach adopted by teachers in presenting the concept to them, students find it difficult to learn chemical bonding. Chemistry teachers in secondary schools find it difficult to teach chemical bonding, because they lack the necessary tools that will enable them help their students to visualise the bonding process.

Using an adaptation of the Waterfall Model of software development, the researcher developed the chemical bonding educational software package used in this study. The research also developed an instrument, Software Rating Scale (SRS), using the 14 most important criteria used by educational software evaluation consortium (Biteer and wighton, 1987), for rating the quality of the chemical bonding educational software package. The internal consistency of the instrument was 0.81, calculated using Cronbach Alpha method. Curriculum experts and Teachers of chemistry validated the instrument. Next, this study investigated the effect of the CBISP on students' academic achievement and interest on chemical bonding. The study also investigated the influence of gender and location on students' achievement and interest in chemical bonding.

Twelve research questions guided the study and twelve hypotheses were tested at $p < 0.05$. Relevant literature review indicated that earlier research on influence of computer educational software package on chemistry students' achievement and interest in chemistry, used commercially produced software package that was not tailored to the curriculum need of the student. There was no indication of the quality rating of the software package used in the study. From the literature reviewed, the researcher gained on insight into the input needed in designing and developing the educational software package and the instrument for its quality rating.

In the evaluative aspect of the present study, a quasi-experiment, non-randomised control group design was used. Three hundred and eleven (311) senior secondary class one (SSI) students constituted the sample. The sample was drawn from eleven (11) out of 57 public senior secondary schools in Nsukka Education Zone of Enugu State of Nigeria. The 57 senior secondary schools had a total population of 5,996 SSI students during the 2012/2013 academic year. Each of the 57 senior secondary schools in the Nsukka education Zone offers chemistry at the senior school certificate level. Four main instruments developed by the researcher were used for this study, those for treatment (teaching) and those for evaluation and test. They include:

(i) Course of study on chemical Bonding (CSCB)

(ii) Chemical Bonding Instrctional Software Package (CBISP)

(iii) Chemical Bonding Achievement Test (CBAT)

(iv) Students Interest Scale on Chemical Bonding (SISCB).

These instruments were developed, based on the blue print and table of specification prepared for them. To ensure content validity, university chemical educators, measurement and evaluation experts, professional secondary school teachers and Chief examiner in WAEC SSC Chemistry examination validated the instruments. The instruments were pilot tested and data obtained in the tests were used to establish the reliability of the instruments. For CBAT, the internal consistency reliability is 0.87, calculated using Kuder Richardson Formula 20; while that for SISCB = 0.68 and for SRS = 0.81 and CSCB = 0.63 calculated using Cronbach Alpha formula.

The data obtained from the study were analysed, using mean, standard deviation. Analysis of covariance (ANCOVA) . The later was used in testing the hypotheses at 0.05 level of significance. From the data analysis, the following result emerged.

15. Method of teaching has statistically significant effect on students mean achievement in chemical bonding.

16. Gender has no statistically significant effect on students' achievement in chemical bonding.

17. School location has statistically significant effect on students' mean achievement in chemical bonding.

18. Method has statistically significant effect on students' interest in chemical bonding.

19. Gender has no statistically significant effect on students' interest in chemical bonding.

20. School location has no statistically significant effect on students' mean interest in chemical bonding.

21. The interaction effect of gender and location on students' achievement in chemical bonding is significant.

22. The interaction effect of gender and method on students' achievement in chemical bonding is significant.

23. The interaction effect of location and teaching method on students' achievement in chemical bonding is significant.

24. The interaction effect of gender and location on students' interest in chemical bonding is not significant.

25. The interaction effect of gender and teaching method on students' interest in chemical bonding is significant.

26. The interaction effect of school location and teaching methods on students' interest in chemistry is not significant.

27. The interaction effect of gender, location and method on students' achievement in chemical bonding is not significant.
28. The interaction effect of gender, location and teaching methods on students' interest in chemistry is not significant.

The result was discussed; and based on the discussion their educational implications were highlighted and recommendations made. Limitations of the study were highlighted and suggestions for further studies made.

APPENDIX A_1

Blueprint for Course of Study on Chemical Bonding (CSCB)

Content	No./ % of **Lessons**	**Duration** (Mins.)	No./ % of **Objectives**	No./ % of **Illustrations**	No./ % of **Tables**
1. Periodic table	1 (10%)	40mins	3 (10 %)	1	2
2.Electronic configuration	5 (50%)	200mins	14 (47 %)	7	2
3. Types of Bonds	4 (40%)	160mins	13(43 %)	23	2
Total	10 (100%)	400mins	30 (100%)	31(100%)	6 (100%)

APPENDIX A_2

FEDERAL MINISTRY OF EDUCATION

SENIOR SECONDARY SCHOOL CURRICULUM

CHEMISTRY

FOR

SS 1 - 3

NIGERIAN EDUCATIONAL RESEARCH AND DEVELOPMENT COUNCIL

SS1

THEME: THE CHEMICAL WORLD

TOPIC	PERFORMANCE OBJECTIVES	CONTENT	ACTIVITIES		TEACHING AND LEARNING MATERIALS	EVALUATION GUIDE
			TEACHER	STUDENTS		
5. CHEMICAL COMBINATION	Students should be able to: 1. identify the first twenty elements of the periodic table; 2. write the electronic configuration of atoms of the first 20 elements; 3. explain the concept of atomic numbers; 4. arrange the elements on the periodic table based on their atomic numbers; 5. differentiate between various types of chemical bonding; 6. name compounds by their conventional and IUPAC names;	1. Periodic table (first 20 elements only) 2. Electronic configuration of atoms 3. Types of bonds - a. strong bonds e.g. electrovalent (ionic), covalent, coordinate covalent (Dative bonds); metallic bonds b. Weak bonds e.g. hydrogen bond, van-der waals forces 4. Systems of naming compounds: - conventional - IUPAC	1. Guides students to: - identify the first twenty elements - draw the electronic configuration of these elements - place these elements in their proper position on a blank periodic table template 2. Explains the types of bonds and their characteristics 3. Uses simple demonstrations to illustrate the type of bond in common substances like camphor, common salt (NaCl), sulphur, etc	1. Write down the names and symbols of the first 20 elements 2. Model and draw the electronic configurations of elements 3. Complete the blank periodic table template by placing the elements in appropriate groups and periods 4. Participate in class discussion 5. Watch teacher demonstrations; ask and answer equations	1. Blank periodic table template 2. Models 3. Charts 4. Table salt 5. Sugar 6. Camphor balls 7. Some liquids e.g. oil, water 8. Aerosol	Students to: 1. name the first 20 elements on the periodic table; 2. draw the electronic configuration of the first twenty elements; 3. deduce the relationship between the arrangements of elements on a periodic table and their electronic configuration; 4. state the differences between electrovalent, covalent and dative bonds;

APPENDIX A_3

Blueprint for the construction of the Chemical Bonding Achievements Test (CBAT)

Process objectives	Recall 40%	Comprehension 40%	Application 20% No of items	Total 100%
1. Periodic table 20%	2 (Qus. nos: 2 & 3)	2 (Qus. nos: 4 & 7)	1 (Qus. no: 1)	5
2. Electronic Configuratio n40%	4 (Qus. nos: 5 , 6, 20 & 15)	4 (Qus. nos: 21, 22, 25 & 26)	3 (Qus. nos: 23, 24 & 27)	11
3. Types of Bonds 40%	4 (Qus. nos:11, 12 , 16 & 19)	4 (Qus. nos:8, 9, 10, & 13)	3 (Qus. nos: 14, 17, & 18)	11
Total	10	10	7	27

APPENDIX A_4

Course of Study on Chemical Bonding (CSCB)

This course of study is based on Nigerian Educational Research and Curriculum Development Council (NERDC) National Curriculum for Chemistry in use in secondary schools. The course is meant for students who have studies Basic Science up to JS class 3. It is designed to help students understand what happens during chemical combination in which bonds are formed. The chemical bond is at the heart of chemistry. Therefore understanding chemical bonding and the nature of bonds is very fundamental in the study of chemistry.

This course is presented in ten lessons designed to enable students have a solid foundation needed to study chemistry. At the end of the course, the student should be able to

(i) Explain the process of bond formation;

(ii) Classify the bonds into their various types; and

(iii) State the properties of compounds containing these bonds.

You can now begin your lesson.

Lesson1

Topic: The periodic table

Duration: 40 minutes

Specific objectives: At the end of this lesson, the students should be able to

(i) explain the concept of atomic numbers

(ii) write down the names and symbols of the first 20 elements;

(iii)identify the first 20 elements of the periodic table;

Teaching aid/material

CBISP

Previous knowledge: Students have studied atoms, molecules and elements.

Introduction: Revision of previous knowledge

In the JS Basic Science classes, you studied atoms, molecules and elements. Answer the following questions to refresh your mind.

1. Which of the following is **not** true about an atom?

A. It is made up of protons and neutrons only.

B. It is the building block of an element.

C. It is made up of protons, neutrons and electrons.

D. In an atom, the number of protons is usually equal to the number of electrons

2. Which of the following is not a molecule of gas?

A. O_2

B. H_2

C. Cl_2

D. Ca

3. Which of the following is the definition of an element?

A. A substance which cannot be split into simpler units by ordinary chemical processes.

B. A substance that forms molecules in a chemical reaction.

C. A substance that contains more than two atoms combined together in a chemical reaction.

D. A. substance whose constituents can easily be separated physically.

Presentation

Step 1. The periodic table

In Basic Science class, the atomic number of any particular element is defined as the number of protons in the nucleus of an atom of the element. When elements are arranged in order of increasing atomic number in a horizontal manner and divided up into **periods** of 8 or 18, the elements which appeared in the same vertical columns (or **group**) had similar properties and could be considered as 'families of elements'. Therefore, elements with similar chemical properties appear at regular intervals or periods. Because of this, elements in each column (or **group**) have similar chemical properties and similar electronic configuration. Their atoms have the same number of electrons in their outermost shells. This arrangement is called the **periodic table**. There are several variations of the periodic table, but the one we are using in this lesson is the one recommended by the International Union of Pure and Applied Chemistry (IUPAC). A typical periodic table, as recommend by the International Union of Pure and Applied Chemistry (IUPAC) is shown in Appendix A.1. There are about 118 known elements. You are, however, required to know and identify the first 20 elements in the periodic table. The horizontal rows of the periodic table are called **periods** while the vertical columns are called **groups**.

Steps 2. Identifying elements in the periodic table

For each element in the periodic table, the atomic number, the atomic symbol and often the relative atomic mass is given. For example, see Fig 1., the typical entry for potassium and hydrogen.

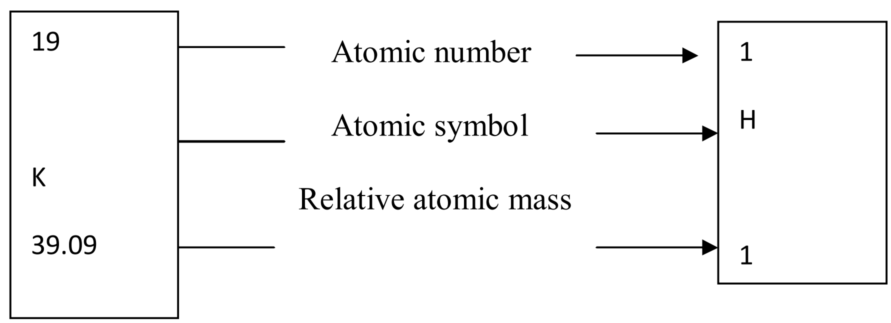


Fig 1 Entry for potassium and hydrogen in the periodic table.

Table1.1 Names, symbols and atomic numbers of the first 20 elements

S/N	Name of Element	Symbol	Atomic number
1	Hydrogen	H	1
2	Helium	He	2
3	Lithium	Li	3
4	Beryllium	Be	4
5	Boron	B	5
6	Carbon	C	6
7	Nitrogen	N	7
8	Oxygen	O	8
9	Fluorine	F	9
10	Neon	Ne	10
11	Sodium	Na	11
12	Magnesium	Mg	12
13	Aluminum	Al	13
14	Silicon	Si	14
15	Phosphorus	P	15

16	Sulphur	S	16
17	Chlorine	Cl	17
18	Argon	Ar	18
19	Potassium	K	19
20	Calcium	Ca	20

Step 4: Significance of periodic table

The periodic table is the most significant tool that chemists use for organising and remembering chemical facts. For example, except for hydrogen, all the elements on the left side and the middle of the periodic table are metallic elements or metals. All the elements share characteristic properties, such as lustre, and high electrical and heat conductivity. All metals, with the exception of mercury (Hg), are solids at room temperature. The metals are separated from non-metallic elements or non-metals by a diagonal like step line that runs from boron (B) to astatine (At).

Hydrogen, although on the left side of the periodic table, is a non-metal. At room temperature some of the non-metals are gaseous, some are solid, and one is liquid. Non-metals generally differ from the metals in appearance, and in other physical properties. Many of the elements that lie along the line that separates metals from non-metals, such as antimony (Sb), have properties that fall between those of metals and those of non-metals. These are called **metalloids**.

The periodic table is significant in systematic classification of elements according to their properties. Examples of such properties include the atomic size, ionisation energy, and electron affinity which occur at regular intervals. This information is valuable in determining the type of compounds which certain elements form. The periodic table therefore makes the study of chemistry easier.

Evaluation: How much have you learnt?

Choose the options that answer the following questions.

1. Atomic number is

A. the total number of protons plus neutrons in the atom.

B. another term for isotopes.

C. the number of protons in the nucleus of an atom.

D. the number of electrons plus neutrons in the atom.

2. What is the symbol of chlorine and in what group is the element located in the periodic table?

A. Cl, in group 17

B. Ch, in group 4

C. Cl, in group 18

D. C, in group 10

3. Which of the following pairs of elements would you expect to show the greatest similarity in physical and chemical properties?

A. Ne and Be

B. He and Ne

C. Al and Ne

D. S and Al

4. Which of the following elements have the atomic number 20?

A. Magnesium

B. Silicon

C. Calcium

D. Argon.

Lesson 2

Topic: Electronic configuration of atom

Duration: 40 minutes

Specific objectives: By the end of the lesson, the students should be able to:

(i) distinguish between the Bohr's model and the quantum mechanics or wave mechanics model of atom;

(ii) distinguish between orbit and orbital.

Teaching aid/material

CBISP

Previous knowledge: Students have studied atomic theory.

Introduction: Revision of previous knowledge – The Atomic Theory

You already know from atomic theory that the atom is made up of three elementary sub-particles namely, the electron, neutron and proton. You also know that the proton has a positive (+) charge and a relative mass of 1 (measured on the standard scale of carbon-12). The Electron has a negative (-) charge and a negligible mass of about 5.0×10^{-3} or 0.0005.

The size or magnitude of the charge on the proton is equal to that on the electron. The neutron has a relative mass of 1 and no charge.

Presentation

Step 1: Introduction
In the present lesson, you will study how the various sub-atomic particles are arranged inside the atom. Two models of the atoms namely the Bohr's model and quantum mechanical or wave mechanical model shall be studied.

Step 2: Energy levels in the atom

For you to understand how the sub-atomic particles are arranged in the atom, the following information must be noted.

(i) There are certain energy levels available in the atom.

(ii) The energy levels are arranged in groups.

(iii) These groups of energy levels are known as ***electron energy shells.***

Step 3. The Bohr model of the atom

Niels Bohr studied the hydrogen atom and based on his findings postulated that the electrons were restricted to certain energy levels, and that the electrons move along circular orbits around the nucleus. . The orbits are sometimes represented by the letter K,L,M,N,O,.. or they may be numbered 1, 2, 3, 4, 5, .. respectively, counting outwards from the nucleus. These numbers are called the principal quantum numbers, n. Bohr's model explained the structure of hydrogen atom, which can be pictured as shown in Fig. 2.1.

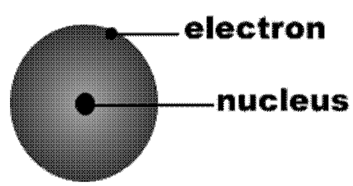


Fig.2.1 Bohr's model of the structure of hydrogen atom

Hydrogen is the simplest atom with only one electron. The Bohr model introduced a single quantum number, n, which is a positive integer, to describe an orbit. The word '***quantum***' means 'fixed amounts' of smallest quantity of energy that can be emitted or absorbed as electromagnetic radiation when an electron moves from one energy level to the other. For the hydrogen atom, the allowed energies are the same as those predicated by Bohr model. However, the Bohr model assumes that the electron is in a circular orbit of some particular radius about the nucleus. The Bohr model could not be applied to more complex atoms such as potassium, which has 19 elections.

Step 4. The quantum mechanical model of the atom

In the quantum mechanical model, the electron's location cannot be described so simply. Due to the extremely small mass of electron, it would be impossible to determine experimentally the exact path and velocity of an electron in an atom. This is in accordance with Heisenberg *uncertainty principle*. By considering the wave properties of an electron, it was possible to calculate the probability of finding an electron in a particular position.

In the quantum mechanical model, we therefore speak of the probability that the electron will be in a certain region of space in the atom at a given instant. The probability of finding the electron in various regions of an atom is shown in Fig2.2.

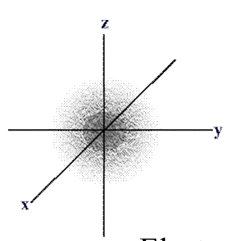


Fig2.2 Electron-density distribution

In this diagram, the density of the dots represents the probability of finding the electron. The regions with a high density of dots correspond to regions where there is a high probability of finding the electron. If the probability of finding the electron in hydrogen atom at a particular distance from the nucleus is plotted as a radial charge density against the distance from the nucleus, a spherical shape fairly close to the nucleus will be obtained.

This shape represents the volume within the atom where there is the highest probability of locating the electron. This volume is called **atomic orbital**. An orbital (quantum mechanical) model is not the same as an orbit (Bohr model). The quantum mechanical model does not refer to orbits, because the motion of the electron in an atom cannot be precisely measured or tracked.

Evaluation: How much have you learnt?

Choose the best options that answer correctly the following questions.

1 Which of the following is **not** true about the atom?

A. There are certain energy levels available in the atom.

B. Energy levels in the atom are arranged in groups.

C. There is only one energy level in the atom where the electrons can be located.

D. Groups of energy levels in the atom are also known as shells.

2. Which of the following is not true about the Bohr model of the atom?

A. Electrons move along a circular orbit of some particular radius about the nucleus.

B. Electrons are restricted to certain energy levels.

C. The model can accurately explain the structure of hydrogen aton

D. Bohr model is used to explain better the structure of complex atoms with many electrons.

3 The orbits in the Bohr atom are sometimes represented by the letter, K,L,M,N,O,.. or they may be numbered 1,2,3,4,5,… respectively. What is the name given to the number?

A. Principal quantum number
B. Special quantum number
C. Auxiliary quantum number
D. None of the above.

4 Which of the following is true about the quantum mechanical model of the atom?

A. The location of the electron is easily determined.
B. We are concerned about the probability of locating the electron at a given instant in a certain region of space in the atom.
C. It does not respect the Heisenberg uncertainty principle.
D. It cannot explain the structure of hydrogen atom.

LESSON 3

Topic: Quantum Numbers (Energy Levels in the atom)

Duration: 40 minutes

Specific objectives: By the end of the lesson, the students should be able to

(i) state the four quantum numbers used in describing an orbital;

(ii) give the values of the various quantum numbers.

Teaching aid/material

CBISP

Previous knowledge: Students have studied the quantum mechanical model of the atom.

Introduction: Revision of Previous Knowledge

In the previous lessons you studied the quantum mechanical model of the atom. In the quantum mechanical model, the electron's location cannot be described so simply. Due to the extremely small mass of electron, it would be impossible to determine experimentally the exact path and velocity of an electron in an atom. You also studied the Bohr's model of the atom. You saw that the Bohr's model of the atom has certain limitation, it could not be applied to more complex atoms such as potassium, which has 19 elections. The Bohr model introduced a single quantum number, n, to describe an orbit.

Presentation

Step 1: Four quantum numbers of quantum-mechanical model of the atom

The quantum-mechanical model used four quantum numbers to describe an orbital. The four quantum numbers are

i) The principal quantum number, n;

ii) The angular momentum quantum number, l;

iii) The magnetic quantum number, m; and

iv) The spin quantum number, s.

These four quantum numbers are required to describe completely the energy state of an electron in the atom.

Step 2: What the quantum numbers denote

The principal quantum number, n, denotes the main or principal quantum energy shell in which the electron is found, where n = 1, 2, 3, 4 etc. Letters K, L, M, N, etc are also used to represent the orbital, where the numbers and letters are corresponding.

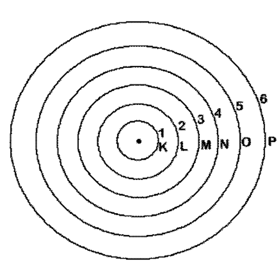


Fig3.1 Main or principal energy shells in the atom.

The *angular momentum quantum number*, *l,* defines the shape of the orbital, and has values from 0 to (n-1) for each value of n. The value of *l* for a particular orbital is generally designated by the letters *s*, *p*, *d* and *f*. These letters correspond to *l* values of 0, 1, 2, and 3 respectively, as shown in Table 4.1

Table 4.1 `

Value of *l*	0	1	2	3
Letter used	*S*	*P*	*d*	*f*

The magnetic quantum number, *m*, describes the orientation of the orbital in space, and can have values between – l and + l including zero. That is – l, 0, l.

The spin quantum number, ***s***, indicates the two opposite directions in which electrons can spin. The two possible values allowed for ***s*** is +1/2 or -1/2. The electron spins about an axis as shown in Fig 3. 2.

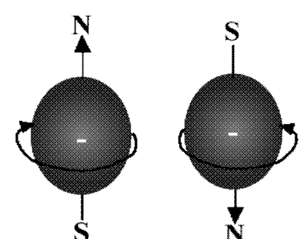


Fig.3.2 Spinning of electron about its axis

Step 3 Electron shells

The collection of orbitals with the same value of n is called *electron shell*. All the orbitals that have n = 3, for example, belong to the third shell. The set of orbitals that have the same n and *l* values is called a sub-shell.

Each sub-shell is denoted by a number, the value of n, and a letter *s*, *p*, *d*, or *f* that corresponds to the value of *l*. for example, the orbitals that have n = 3 and *l* = 2 are called 3d orbitals and are in the 3*d* sub-shells (see Fig 3.3)

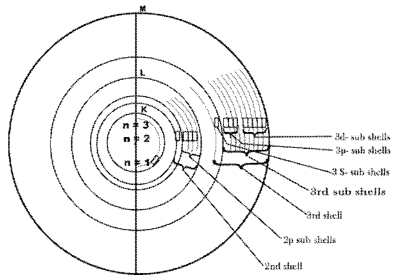


Fig 3.3 Electron shells and sub-shells in the hydrogen atom

Step 4 Values of the quantum numbers

The following note is a summary of the outcome of studies on the various quantum numbers and subshells.

1. The shell with principal quantum number, n will consist of exactly n subshells. Each subshell corresponds to different allowed value of l from 0 to (n-1).

2. Each subshell consists of a specific number of orbitals. Each orbital corresponds to a different allowed value of m. For a given value of *l*, there are (2*l* + 1) allowed values of m, ranging from – *l* to +*l*.

3. The total number of orbitals in a shell is n^2**,** where n is the principal quantum number of the shell. For n = 4, for example, the number of orbitals for the shells is 1, 4, 9, and 16. This is presented in Table 3.2

`Table 3.2 Energy levels in the atom

n	Possible value of l	Subshell designation	Possible value of m	Number of orbitals in subshell	Total number of orbitals in shell
1	0	1*s*	0	1	1
2	0 1	2*s* 2*p*	0 -1, 0, 1	1 3	4

3	0 1 2	3s 3*p* 3*d*	0 -1, 0, 1 -2, -1, 0, 1, 2	1 3 5	9
4	0 1 2 3	4*s* *4p* *4d* *4f*	0 -1, 0, 1 -2, -1, 0,1, 2 -3, -2, -1, 0, 1, 2, 3	1 3 5 7	16

Evaluation: How much have you learnt?

Choose the options that correctly answer the following questions:

1. The main limitation of the Bohr model of the atom is that

A. it could not explain the structure of hydrogen atom.

B. it has the four quantum numbers.

C. it could not explain the structure of complex atoms

D. it contains no nucleus

2. the principal quantum number, n denotes

A. the main energy level in the atom.

B. the angular momentum of the electron.

C. the orientation of the orbital in space.

D. the number of neutrons in the atom.

3. the shape of the orbital is defined by

A. Angular momentum quantum number, *l* .

B. Spin quantum numbers, *s*.

C. The number of neutrons in the atom.

D. None of the above.

4. Where n is the principal quantum number of the shell, the total number of orbitals in a shell is given by the formula.

A. 2n

B. n^2

C. 2(n +1)

D. 2n + 1

LESSON 4

Sub-topic: Pauli's Exclusion Principle

Duration: 40 minutes

Specific objectives: By the end of this lesson, the student should be able to

(i) state the Pauli's Exclusion Principle.

(ii) apply the principle in filling atomic orbitals with their appropriate number of electrons.

Teaching aid

CBISP

Previous knowledge: Students have studied the energy levels in the atom.

Introduction: Revision of previous knowledge

In your previous lesson, you studied the energy levels or quantum numbers in an atom. There are four of such quantum numbers namely:

(i) the principal quantum number;

(ii) the subsidiary or azimuthal quantum number;

(iii) the magnetic quantum number; and

(iv) the spin quantum numbers.

The symbols of the various quantum numbers are *n, l, m* and *s* respectively. The quantum numbers are used to work out the electronic configuration of atoms of known elements.

Presentation

Step 1: Pauli Exclusion principle

The Pauli Exclusion principle states that two electrons in the same atom cannot have the same values for all the four quantum numbers. It therefore means that no two electrons in the same atom can behave alike or in the same manner, that is, no two electrons in an atom have the same quantum of energy. This is because the *s*, *p*, *d* and *f* orbitals in which the different electrons move about in different directions, have different shapes such as spherical and dump-bell shapes.

Step 2: Location of the electron in its orbital

You will recall that in the Bohr's model of the atom, the electron is restricted to a definite position in a circular orbit. However, the wave–mechanics model shows that there is a probability that the electron may not be located in an exact position as predicted by the Bohr's model.

When the probability of locating an electron in a given spherical shell around the nucleus is plotted against the distance, r, of the electron from the nucleus, for the hydrogen atom, the graph show that the probability of locating the electron increases as the radius between the electron and the nucleus decreases.

Step 3: Shapes of the *s* and *p* orbitals

Electrons located in a given orbital do not have the same quantum four numbers (or amount of energy), the quantum numbers are the principal quantum number (n); subsidiary or azimuthal quantum number (l) ; magnetic quantum number (m); and spin quantum numbers (s). The electrons move about the nucleus of the atom in different directions. The result of the movement of the *s*-electrons is a spherical cloud around the nucleus. Thus, *s*, orbitals are symmetrically spherical (Fig 4.1).

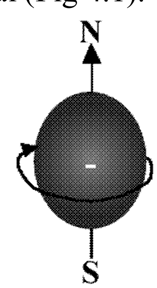


Fig 4.1 Shape of the *s*-orbital

The *p*-electrons move about the x, y and z axes that are at right angles to each other. There are three *p* orbitals, which are differentiated and represented as P_x, P_y and P_z. The p-orbital when full has six electrons distributed in pairs among the P_x, P_y and P_z sub-orbitals. The electron clouds that result from this movement align themselves along the various axes and are dumb-bell shaped (Fig 4.2).

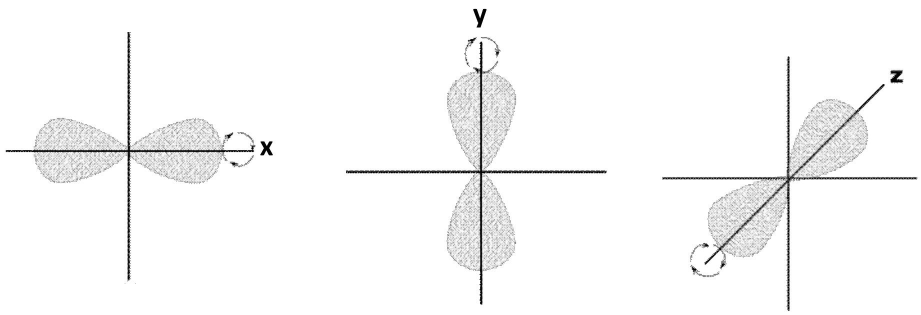


Fig **4.2 Three *P*-orbitals**

Evaluation- What have you learnt?
Choose the options that answer the following questions.

1. Which of the following statements is the Pauli's Exclusion principle ?

A. Two electrons in the same atom cannot have the same values for all the four quantum numbers.

B. Two electrons in the same orbital must be involved in chemical reactions.

C. Electrons in an atom can be precisely located in an orbital.

D. Two electrons in the same orbital must spin in the same direction.

2. The shape of *s*-orbitals is

A. dumbbell.

B. symmetrically spherical.

C. not in a form that can be described.

D. none of the above.

3. The *p*-orbitals are how many in number?

A. 4

B. 3

C. 2

D. 5

4 Which of the following is used to differentiate the various *p*-orbitals in an atom?

A. P_x, P_y, P_z

B. P_{xy}, P_y, P_z

C. $P_{y\text{-}z}$, P_x, P_{zy}

D. P_{yx}, P_z, P_{yz}

Lesson 5

Topic: The octet rule and Lewis structure

Duration: 40 minutes

Specific Objectives: By the end of this lesson, the student should be able to

(i) state the octet rule

(ii) apply the octet rule to explain the structure of atoms in a chemical combination

(iii) use Lewis symbols to show the valence electrons of atoms of the first 20 elements in the periodic table.

Teaching Aids

1. Table showing Lewis symbols of the first 20 elements in the periodic table
2. CBISP.

Previous knowledge: The students have studied Pauli's Exclusion Principle.

Introduction: Revision of previous knowledge

In your previous lesson, you learnt that no two electrons in the same atom can have the same values of all the four quantum numbers. This is called the Pauli's Exclusion Principle. This principle simply means that no two electrons in the same atom can behave alike or in the same manner.

Step 1: The octet rule

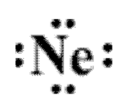
In chemical reactions, atoms gain, lose or share electrons to have the same number of electrons as the noble gas closest to them in the periodic table. The noble gases have very stable electron arrangements, which make them to have low affinity for additional electrons at the outermost orbital. That is why noble gases generally are not chemically reactive. Because all noble gases (except He) have eight valence electrons, many atoms undergoing reactions also end up with eight valence electrons. Valence electrons are the electrons found in the outermost shell of an atom.

The observation that noble gases have eight valence electrons, and that many atoms undergoing reactions end up with eight valence electrons is the basis for the octet rule. The octet rule states that atoms tend to gain, lose or share electrons until they are surrounded by eight electrons in the outermost orbital. An octet of electrons is made up of full *s* and *p* sub-shells in an atom.

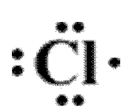
Step 2: Lewis symbols

The Lewis symbols for an element is made up of the chemical symbol for the element plus a dot for each valence electron. The electrons involved in chemical bonding are the valence electrons, which for most atoms are those found in the outermost occupied shell of an atom. The Lewis symbol is the simplest way of showing the valence electrons in an atom and tracking them in the course of bond formation.

In terms of Lewis symbol, an octet can be thought of as four pairs of valence electrons arranged around the atom, eg. The Lewis symbol for neon is



Chlorine, for example, has the electronic configuration of $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$ while its Lewis symbol is



Step 3: Electronic Configuration and Lewis Symbols

From what you have done so far, let us write the electronic configuration and Lewis Symbols of atoms of some elements.

Table 5.1

Element	Symbol	Electronic configuration	Lewis symbol
Helium	He	$1s^2$	•He•
Lithium	Li	$(He)2s^1$	Li•
Beryllium	Be	$(He)2s^2$	•Be•
Neon	Ne	$(He)2s^2\ 2p^6$	$:\overset{\bullet\bullet}{\underset{\bullet\bullet}{Ne}}:$
Sodium	Na	$(Ne)3s^1$	Na•
Argon	Ar	$(Ne)3s^2\ 3p^6$	$:\overset{\bullet\bullet}{\underset{\bullet\bullet}{Ar}}:$
Potassium	K	$(Ar)4s^1$	K•
Calcium	Ca	$(Ar)4s^2$	•Ca•

Evaluation: What have you learnt?

Choose the options that best answer the following questions.

1. Which of the following sentences is true about Lewis symbol of an element?

A. It is made up of the chemical symbol for the element plus a dot for each valence electron.

B. It consists of the chemical symbol for the element plus a dot for each neutron in the atom

C. It consists of the chemical symbol for the element plus a dot for each electron in the *p* orbital.

D. It consist of the chemical symbol for the element plus a dot for all available electron in the atom.

2. Which of the following is the Lewis symbol for potassium

A. **K** ● B. ● $\dot{\mathbf{P}}$● C. **P** ● D.● **Km** ●

3. Which of the following is octet rule?

A. Atoms tend to gain, lose or share electrons until they are surrounded by eight electrons.

B. Every atom must gain its eight electrons in a chemical reaction.

C. All eight electrons in the *s* and *p* orbitals must behave alike in a chemical combination.

D. It is not possible for any atom to undergo reactions unless it has eight electrons in the outermost shell

4. Which of the following is the significant value of the Lewis symbol?

A. It explains readily why bonds are formed.

B. It shows that elements have symbols for bonding.

C. It is the simplest way of showing the valence electrons in an atom and tracking them in the course of bond formation.

D. It shows that four pairs of electrons must be involved in bond formation.

LESSON 6

Topic: Electronic configuration of the first 20 elements

Duration: 40 minutes

Specific Objective: At the end of this lesson, students should be able to

(i) indicate and represent the principal quantum number and the subsidiary quantum number in an atom;

(ii) use arrows to represent electrons and show direction of their spin in electron sub energy level or sub shell;

(iii) draw orbital diagrams of the atoms of the first 20 elements;

(iv) write the electronic configuration of atoms of the first 20 elements.

Teaching Aid

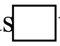
CBISP

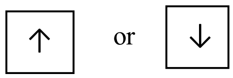
Previous knowledge: The students have studied Lewis symbols

Introduction: Revision of previous knowledge

In your previous lesson, you studied symbols. The Lewis symbols for an element is made up of the chemical symbol for the element plus a dot for each valence electron. The Lewis symbol is the simplest way of showing the valence electrons in an atom and tracking them in the course of bond formation.

Presentation Step 1 Order of arrangement of electrons in an atom

Electrons in an atom are arranged in the sub-shells in order of increasing energy levels. Thus, electrons with the lowest energy are found at the ground state. The various energy levels or sub-orbitals in the atom are the *s*, *p*, *d*, and *f* orbitals. Numbers are used to indicate the principal quantum numbers and letters the subsidiary quantum numbers of these sub-orbitals. For example, in hydrogen with atomic number of 1, the electron is found in the 1s sub-shell. The number indicates the principal quantum number while the letter indicates the subsidiary quantum number. Hydrogen has only one electron in the sub-shell, this is indicated as follows: $1s^1$. The index figure added shows the number of electrons in each set of orbitals. Arrow is used to represent the electron, and to show the direction of its spin while a box is us  to represent the sub-shell. For example,

. 

In the given example, the two electrons in different sub-shells are spinning in opposite directions.

Step 2: Orbital diagram and the distribution of electrons in the atom.

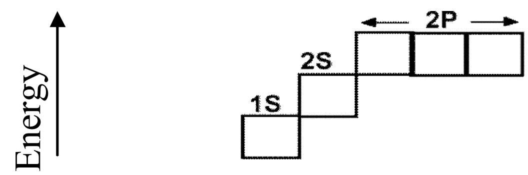


Fig 6.1 Orbital energy level diagram

In hydrogen atom, electrons are distributed as shown below (Fig 6.2).

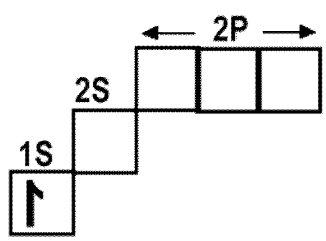
Element	Orbital electrons	Electron sub-shell
Hydrogen	$1s^1$	

Fig 6.2 Electron distribution in hydrogen

In helium atom, there are only 2 electrons which can be accommodated in the 1*s* orbital. So, the electronic configuration of helium can be written as $1s^{2,}$ and the orbital diagram is as shown below (Fig 6.3).

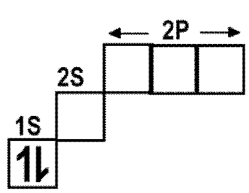
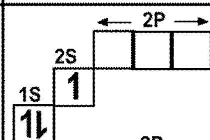
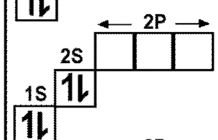
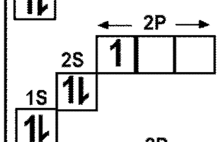
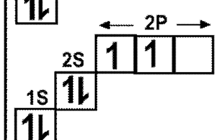
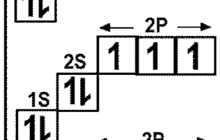
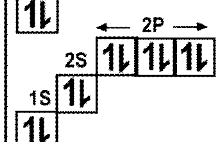


Fig 6.3Electron distribution in helium

For the next other atoms with higher atomic numbers, once the 1*s* orbital is filled up, the remaining electrons will move to the 2*s* orbital, and thereafter to the *p*-orbitals once the 2*s* orbital in filled. For electrons to occupy the *p*-orbitals, they must follow the Hund's rule, which states that electrons occupy each orbital singly first before electron-pairing takes place.

The orbital energy level diagrams for the following elements: Lithium, Beryllium, Boron, Carbon, Oxygen and Neon are given in Table 6.1

Table 6.1 Orbital energy level diagram of some elements

Element	Atomic No.	Electron Sublevel	Electronic Configuration
Lithium	3		$1S^2\ 2S^1$
Berullium	4		$1S^2\ 2S^2$
Boron	5		$1S^2\ 2S^2\ 2P^1$
Carbon	6		$1S^2\ 2S^2\ 2P^1$
Oxygen	8		$1S^2\ 2S^2\ 2P^4$
Neon	10		$1S^2\ 2S^2\ 2P^6$

Step 2: Electronic configuration of the atoms of the first 20 elements in the Periodic Table

From what we have done above, it is easy now for us to write the electronic configuration of the atoms of the first 20 elements as in Table 6.2.

Table 6.2 Electronic configuration of the atoms of the first 20 elements in the Periodic Table

Element	**Symbol**	**Atomic Number**	**Electronic configuration**
Hydrogen	H	1	$1s^1$
Helium	He	2	$1s^2$
Lithium	Li	3	$1s^2\ 2s^1$
Beryllium	Be	4	$1s^2\ 2s^2$
Boron	B	5	$1s^2\ 2s^2\ 2p^1$
Carbon	C	6	$1s^2\ 2s^2\ 2p^2$
Nitrogen	N	7	$1s^2\ 2s^2\ 2p^3$
Oxygen	O	8	$1s^2\ 2s^2\ 2p^4$
Fluorine	F	9	$1s^2\ 2s^2\ 2p^5$
Neon	Ne	10	$1s^2\ 2s^2\ 2p^6$
Sodium	Na	11	$1s^2\ 2s^2\ 2p^6\ 3s^1$
Magnesium	Mg	12	$1s^2\ 2s^2\ 2p^6\ 3s^2$
Aluminium	Al	13	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$
Silicon	Si	14	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$
Phosphorus	P	15	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$
Sulphur	S	16	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$
Chlorine	Cl	17	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$
Argon	A	18	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
Potassium	K	19	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$
Calcium	Ca	20	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

Step 3: Electronic configuration and the periodic table

When the electronic configuration of the atoms of the elements in the periodic table is considered, it will be observed that atoms of elements in each vertical column have the same number of electrons in their outermost shells. For example atoms of Li, Na, and K each has one electron in the outermost shell; and they are all very reactive metals. F and Cl are very reactive nonmetals, and their atoms have each 7 electrons in their outermost shell. The atoms of the rare gases, neon and argon have the same number of electrons in their outermost shell.

From the periodic table and the electronic configuration of atoms, we can easily see the number of electrons in the outermost shells which take part in chemical combinations. We can predict or guess which atoms or elements can combine together in a chemical reaction.

Evaluation: How much have you learnt?

Choose the options that answer the following questions correctly.

1. Which element has the following electronic configuration of its atom: $1s^2 2s^2 2p^6 3s^2$

A. Oxygen

B. Magnesium

C. Chlorine

D. Silicon

2. Which of the following is the Hund's rule?

A. Electrons occupy each orbital singly first before electron-pairing takes place.

B. Electrons must gain energy before taking part in a reaction.

C. Electrons must be attracted by protons in the atom.

D. None of the above.

3. The index figure in $2s^1$ shows

A. the number of neutrons in each set of orbital.

B. the atomic number of the atom.

C. the number of electrons in each set of orbital.

D. the number of protons in the atom.

4. How many electrons are found in the outermost shell of the following set of atoms: Li, Na, and K
A. 2
B. 7
C. 3
D. 1

LESSON 7

Sub-topic: Types of bonds - Electrovalent (ionic) bond

Duration: 40 minutes

Specific objectives. At the end of this lesson, the student should be able to

(i) define ionic bonding;

(ii) explain how ionic bonds are formed;

(iii) state the conditions for ionic bonding to take place; and

(iv) state at least three properties of ionic compound.

Teaching materials

CBISP

Introduction: Bonding

Bonding takes place when atoms combine to form a compound. There are three main types of chemical bonding namely ionic bonding or electrovalency, covalency (or covalent bonding) and metallic bonding. There are other types of bonding namely hydrogen bonding and van-der waals forces. We shall study each of these types of bonding in detail.

step 1: Ionic bonding

Ionic bonding is the chemical bonding in which bonds are formed between atoms of very active metallic elements and those of very active nonmetals. For ionic bonding to occur, two conditions are important:

i. The atoms of one element must be able to lose one or two electrons without undue energy input.

ii. The atoms of the other elements must be able to accept one or two electrons without under energy input.

These conditions restrict ionic bonding to compounds between the most active metals (Groups 1,2 part of 3, metals that form cations), and the most active nonmetals (Groups 16, 17 and Nitrogen that form anions.

Step 2: Ionic bonding process

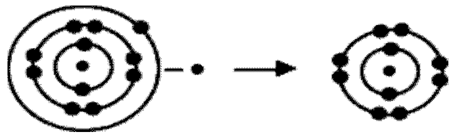
In a fully ionic compound, an electron or electrons are transferred from one element to another, to give positive ion called cation, and negative ion called anion. Sodium chloride (NaCl), which is a good example of ionic compound consists of the ions Na^+ (sodium atom less one electron) and Cl^- (chlorine atom plus one electron).

During chemical combination of sodium and chlorine atoms, the single electron from the outermost shell of the sodium atom moves over to the outermost shell of the chlorine atom. In this way, the two ions are produced. The sodium ion is positively charged, as Na^+ , by the nuclear proton left in excess after the electron has moved away, and the electron structure is now $1s^2\,2s^2 2p^6$ or (2,8). The chlorine ion is negatively charged, as Cl^-, by the electron it received, and its electron structure is now $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ (2,8,8,). In both cases, the ions have now the electron structure of a rare gas (neon and argon respectively) with the outermost shell electron octet. The process of the formation of the ions is given in the following equation:

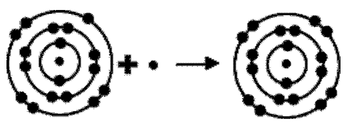
$Na - e \longrightarrow Na^+$

$Cl + e \longrightarrow Cl^-$

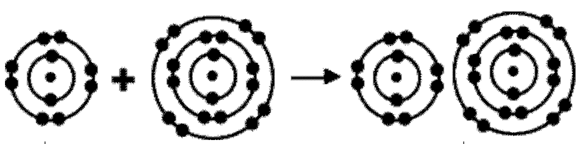
The process can be represented in the following diagram



You can observe that the size of the ion (Na^+) formed is smaller than that of the atom (Na). In the case of chlorine, the opposite of the above is observed as shown in the following diagram:



To form sodium chloride, the sodium ion and the chlorine ion are attracted to each other and are held together by electrostatic force of attraction.

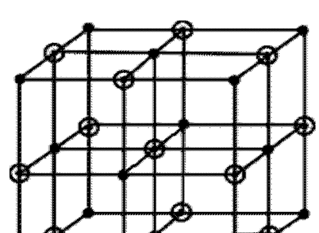


The equation for this reaction can be written as: $Na + Cl \longrightarrow Na^+ Cl^-$

The electrostatic force of attraction resulting from their opposite charges is the chemical bond that is found in sodium chloride. In the solid state the ions are held together by electrostatic force of attraction; in aqueous solution the ions are solvated and free to be mobile. In the vapour the compound is made up of ion-pair, not molecules. This is because sodium chloride compound is made up of aggregate of ions.

Step 3: Structure of sodium chloride

The ions in sodium chloride arrange themselves into a crystal lattice, in such a way that there is no specific pairing of ions (Fig 7.1).



● Sodium ion ○ Chlorine ion

Fig 7.1 Structure of sodium chloride

Step 4: Other examples of ionic combination

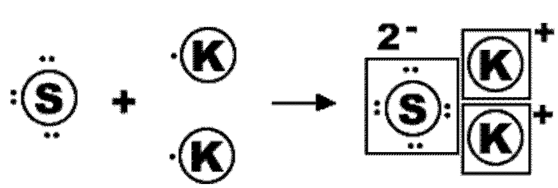
(i) **Potassium Sulphide** $2K^+S^{2-}$

In the formation of potassium sulphide, $2K^+ S^{2-}$, two atoms of potassium combined with one atom of sulphur. The electronic configuration of potassium atom is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$ while that of sulphur is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$. In a chemical reaction, the lone electrons in the outermost shell of each of the two atoms of potassium move over to the outermost shell of the sulphur atom as shown in the equation.

$$2[1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1] + 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4 \longrightarrow 2[1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6]^+[1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6]^{2-}$$

Two potassium ions ($2K^+$) and one sulphur (S^{2-}) ion are produced, which now have external octet of electrons (complete *P* sub-shells). The oppositely charged ions are attracted to each other and held together by electrostatic force of attraction to form ionic lattice. The reaction equation is $2K+S \longrightarrow 2K^+S^{2-}$

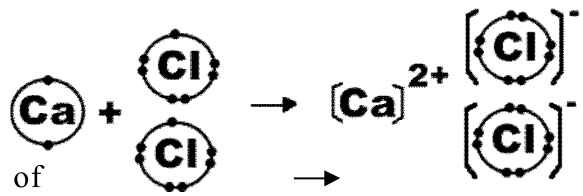
Pictorially, the reaction can be represented as follows, where the outermost electrons are shown



(ii) Calcium chloride, $CaCl_2$

In a similar way, a calcium atom could lose two electrons to two chlorine atoms to form a calcium ion Ca^{2+} and two chloride ions Cl^-, that is calcium chloride $CaCl_2$.

Showing the outermost shell electrons only, the reaction may be represented as follows:



The equation of the reaction is $Ca + Cl_2 \rightarrow CaCl_2$.

Other examples of ionic compounds are MgO, CaO, LiCl, KBr.

Step 5: Properties of ionic (electrovalent) compounds

1. The compounds are made up of positive and negative ions (aggregates of ions) arranged together in a regular way in lattice.
2. The melting and boiling points of ionic compounds are usually high.
3. The compounds are very hard.
4. Ionic compounds conduct electricity when melted or in solution.
5. Ionic compounds are usually soluble in polar solvents such as water, but rarely soluble in organic liquids.

Evaluation: How much have you learnt?

Choose the options that best answer the following questions:

1. Ionic bonds are formed when

A. atoms of very active metallic elements react with those of very active nonmetals.

B. atoms of very active metallic element react with each other.

C. atoms of very active nonmetallic elements react with themselves.

D. none of the above.

2. Which of the following is not a condition for ionic bonds to be formed.

A. Ability of atoms of one element to lose one or two electrons without much energy input.

B. Ability of atoms of the other element to receive one or two electrons without much energy input.

C. The reacting atoms must belong to the same group in the periodic table.

D. A and B only

3. Which of the following is not a property of an ionic compound?

A. Low melting and boiling point.

B. Ability to conduct electricity.

C. Capability to dissolve in polar solvents.

D. it contains no molecules but aggregates of ions.

4. Which of the following is not an ionic compound?

A. LiCl

B. HCl

C. CaCl

D.KCl

LESSON 8

Topic: **Covalent bonding**
Duration: **40 minutes**
Specific Objectives: At the end of this lesson, the student should be able to

i. Explain covalent bonding or covalency

ii. Use Lewis symbols to denote bonding in covalency

iii. Use straight lines to denote covalent bonds

Teaching Aids/Materials

CBISP

Presentation

Step 1: Formation of covalent bonds

Covalent bond is formed when there is a simultaneous sharing of a pair of electrons (or, less frequently, just one electron) by two atomic nuclei. The simplest example is the hydrogen molecules, where each atom of a hydrogen molecule contributes one electron to the bond. This may be represented using the Lewis symbols as follows

$$H\cdot + \cdot H \longrightarrow H : H \text{ or } H\text{-}H$$

A clearer picture of this reaction is obtained by considering the overlap of the electron orbitals of the atoms concerned. Where the electron orbitals overlap, there is a region of increase electron density (negatively charged) toward which the positively charged atomic nuclei are attracted.

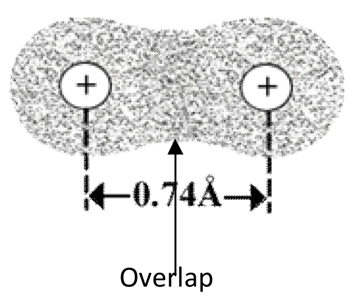
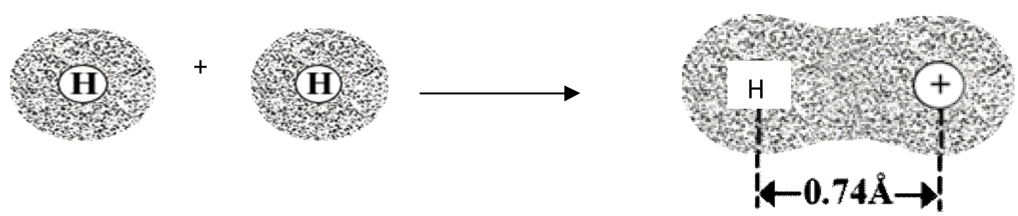


Fig 8.1 Overlap of electron orbitals resulting in covalent bonding in H_2

Step 2 Conditions for the formation of covalent bonds

To form a covalent bond each atom must have an unpaired eletron in their outermost orbital; alternatively, one element may contribute two electrons to form a co-ordinate bond. For example, each atom of hydrogen has one ***s*** electorn, whose orbital is spherical. In a hydrogen molecule these two electrons occupy a molecular orbital which involves both nuclei. A molecular orbital is

the orbital that result, and contains the shared electron pairs when a molecule is formed.



a) spherical single **s** electron orbitlas in hydrogen b) Hydrogen molecular orbital(σ overlap bonding orbital)

Fig 8.2 Bonding in hydrogen.

Covalent bonding of this type, which occurs through orbital overlap along the axis joinging the two nuclei to give a molecular orbital, which is symmetrical about this axis is known as sigma (б) bond. It occurs through S-S orbital overlap and through, S-P overlap and through overlap between S or P orbitals.

Step 3: Bond length and strength

There is a position of minimum potential energy, where the internuclear distance is such that this attraction and the repulsion between the nuclei are just balanced. Thus, the bond has a definite length and strength. The strength of a bond between two atoms is the energy required to break that bond.The energy is measured in kilojoules per molecule (KJ/mol)

Step 4. Examples of molecules and compounds with covalent bonds

(i) Chlorine (Cl_2) gas

An inert configuration may be attained by sharing of electrons. Consider two chlorine atoms (2Cl) which react to form a chlorine molecule Cl_2. Using the Lewis symbol, the outer most shell electrons of chlorine could be shown diagrammatically as follows (Fig 8.3).

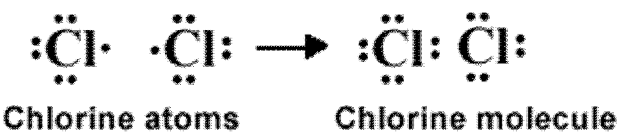
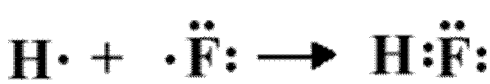


Fig 8.3 Bonding in chlorine

Each of the two chlorine atoms donates one of its outermost orbital electrons; the pair of electrons so donated are located in the overlapped atomic orbitals (that have become a molecular orbital), and the electrons are shared equally between both atoms. Each atom in the molecule therefore has in its outermost shell six electrons, which completely belong to it; plus a share in two more electrons, thereby getting a stable octet like the structure of argon.

ii. Hydrogen Fluoride HF

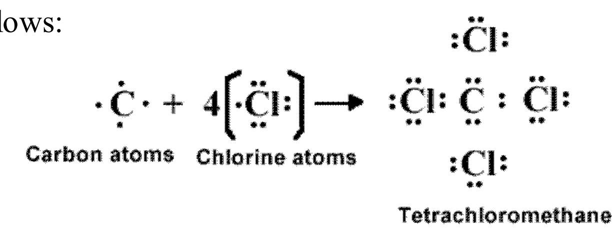
A molecule of hydrogen fluoride is made up of one hydrogen and one fluorine atoms. Using Lewis symbols, the structure can be shown as follows:



Both hydrogen and fluroine atoms have each one electron short of their nearest inert gas structure of helium and argon respectively. To attain a stable configuration of these nearest inert gas, each atom contributes one electron to the other. The pair of electrons so contributed are shared equally between both atoms in the molecule. Hydrogen has in its outermost shell one electron, which completely belong to it; plus a share in two more electrons, thereby getting a stable duplex like the structure of helium. Fluorine has in its outermost shell seven electron, which completely belong to it; plus a share in two more electrons, thereby getting a stable octate like the structure of argon

i. **Tetrachloromethane (CCl_4)**

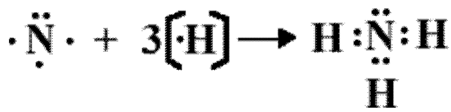
A moelcule of tetrachloromethane (also called carbon tetrachloride) CCl_4 is made up of one carbon and four chlorine atoms which we can represent in a diagram using Lewis symbols as follows:



The carbon atom is four electrons short of the inert gas structure, therefore it makes four bonds and the chlorine atoms are one electron short each, so each of the chlorine atoms forms one bond. By sharing electrons in this manner, both the carbon and all four chlorine atoms attain an inert gas structure.

ii. **Ammonia (NH_3)**

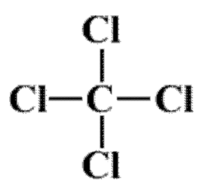
A molecule of ammonia NH_3 is made up of one nitrogen and three hydrogen atoms. Using the Lewis symbosl, this is represented as



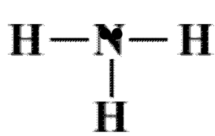
A nitrogen atom has three electrons short of the configuration of argon, the nearest inert gas to it at the periodic table; and each of the three hydrogen atoms has one electron short of the structure of helium, the nearest inert gas. To attain a stable configuration, nitrogen forms three bonds while the hydrogen atoms one bond each. In this example, you observed that one pair of electrons is not involved in bond formation. This one pair of electrons that is not involved in bond formation is known as **a lone pair of electrons**.

Step 5 How to Represent Covalent Bond

Straight lines are used to represent covalent bonds in a molecule. So, in place of Lewis symbol, straight lines can be used to represent the bonds in tetrachloromethane as follows.



Ammonia in written as



Evaluation: What have you learnt?

Choose the option that answer the following questions.

1. Covalent bond in formed when

A. There is a sharing of an electron pair, where each atom contributes one electron to the bond.

B. An octet is attained by loss of electrons.

C. The electron cloud becomes larger in an atom.

D. Two atoms exchange their electrons.

2. Which of the following is a condition for the formation of a covalent bond

A. Two atoms must approach each other with the same speed in a chemical reaction.

B. Each of the two atoms must have an unpaired electron.

C. The shape of the orbitals must be spherical

D. The nucleus of each atom must attract themselves.

3. Which of the following molecules contains a lone pair of electrons?

A. Tetrachloromethare

B. Ammonia

C. Hydrongen fluoride

D. Chlorine molecule

4. Sharing of electrons is not possible in

A. Sodium chloride

B. Hydrogen fluoride

C. Ammonium chloride

D. All of the above

LESSON 9

Topics: **Dative coordinate and metallic bonds**

Duration: **40 minutes**

Specific objectives: At the end of this lesson, students should be able to

i. explain coordinate and metallic bonding;

ii. explain the terms electronegativity and dipoles;

iii. state properties of covalent compounds.

Teching aids

CBISP

Previous knowledge: The students have studied how covalent bonds are formed.

Introduction: Revision of previous knowledge

In your previous lesson, you learnt that a covalent bond is formed when there is a simultaneous sharing of a pair of electrons by two atomic nuclei.

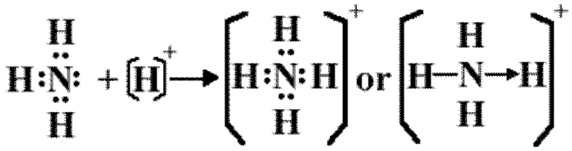
Presentation

Step 1: Explanation of coordinate bonding

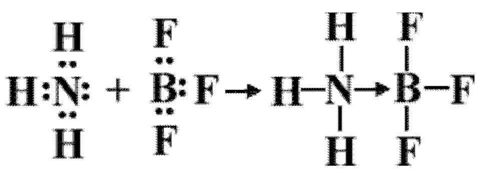
It is possible in a chemical combination that one of two combining atoms donated all the electrons that are shared equally by the two combining atoms to form a bond. This means that a pair of electrons shared by the two combining atoms are donated by only one atom and none from the other. This type of bond is known as **coordinate-covalent** or **dative-covalent** bond. Once a coordinate-covalent bond is formed, it is identical to normal covalent bond.

Step 2: Formation of coordinate bonds in ammonium ion, NH_4^+

Ammonia molecule has a stable electronic configuartion and a lone pair of electrons which it can donate to hydrogen ion in a combination to form ammonium ion NH_4^+ . Using Lewis symbols, we have

In the  above structure, normal covalent bonds are depicted as straight lines joining the two atoms, and arrow is used to show coordinate bond and which atom is donating the electrons.

Ammonia can also donate its lone pair to other compounds such as boron trifluoride. In this way, the boron atom attains the octet.



Adduct

This compound formed when ammonia combines with boron trifluoride is called **adduct** or ammonia boron trifluoride.

Step 3 Metallic bond

A metal, such as copper, is made up of a lattice of rigid spheres (positive ions), embedded in a 'sea' of free valency electrons.

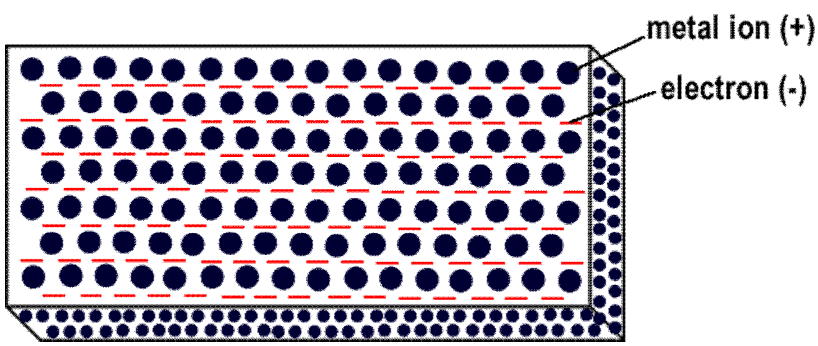
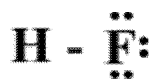


Fig. 9.1 Structure of a metal

The electrons are held on to the metal by electrostatic force of attraction to the cations, and they are evenly distributed throughout the structure. Metallic bond is the electrostatic force of attraction between postive ions of the metal and the electron clouds.

Step 3: Electronegativity and dipoles

When a covalent bond connects two different atoms, for example in the formation of hydrogen fluoride, HF, whose Lewis Structure is



the two eletrons in the bond do not remain equidistant from the two nuclei; they are close to the F atom than the H atom. This means that the electron cloud is distorted, resulting in a partial negative charge on the fluorine atom and a partial positive charge on the hydrogen as shown in Fig. 9.2.

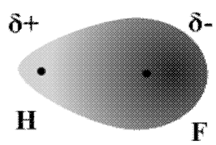


Fig. 9.2.

The F atom attracts the electron pair of the bond more than the H atom does. Fluorine is therefore said to have a higher ***electronegativity*** than hydrogen and so attracts the electrons of the bond more.

Electronegativity refers only to the attraction that an atom has for a pair of electrons in a covalent bond to itself. Because the H-F molecule has two poles, like a magnet, it is called a dipole molecule. Water (H_2O) is a dipole molecule and a polar solvent.

Step 4 Properties of covalent compounds

1. Covalent compounds are not normally soluble in polar solvents, but are soluble in organic or non-polar solvents, such as benzene and tetrachloromethane.
2. They are made up of discrete molecules.
3. They have low melting and boiling points.
4. They are insulators and do not conduct electricity.
5. Covalent compounds usually react slowly.

6. Covalent compounds are often gases, liquids or soft solids with low melting points.

Evaluation: What have you learnt?

Choose the options that answer correctly the following questions.

1. A dative-covalent bond is formed when
   A. a pair of electrons shared by two atoms are contributed equally by each atom.
   B. the pair of electrons shared by two atoms come from the d-orbitals of both atoms.
   C. a pair of electrons shared by two atoms are identical.
   D. a pair of electrons shared by two atoms are contributed from one atom and none from the other.
2. Electronegativity refers to
   A. the attraction that an atom has for a pair of electrons in a covalent bond to itself.
   B. the electron density of the molecule.
   C. utility of the protons to repel each other in an atom
   D. the attraction between two electrons in an atom
3. Which of the following is not a property of a covalent compound
   A. Soluble in organic solvents
   B. Low melting and boiling points.
   C. Composed of discrete molecules.
   D. Conduct electricity.
4. Which of the following is a polar solvent?
   A. Water
   B. Benzene
   C. Tetrachloromethane
   D. None of the above

LESSON 10

Topic: Hydrogen bonding and van der Waals forces

Duration: 40 Minutes

Specific objectives: At the end of this lesson, students should be able to

1. explain hydrogen bonding;
2. explain van der waals forces;
3. explain the effects of hydrogen bond and van der walls forces in a molecule and compound.

Teaching Aids

CBISP

Previous knowledge: Students have studied ionic and covalent bonds.

Introduction: Revision of previous knowledge

In you previous lessons, you studied ionic and covalent bonds. Ionic and covalent bonds are classified as strong and weak bonds respectively. Ionic and covalent bonds could keep atoms and ions in their respective compounds together such that the compounds are either hard solid compounds or soft solid compounds.

Presentation

Step 1: Hydrogen bond

In the present lesson, you will study about some other kinds of bond that are known as *weak bonds* because they are not as strong as ionic or covalent bonds. The hydrogen bond belongs to this group of weak bonds.

The hydrogen bond is an intermolecular force that results when hydrogen is covalently joined to strongly electronegative elements such as fluorine, oxygen and nitrogen. These elements form dipoles with hydrogen, that is, while the hydrogen atom is partially positively charged, the other elements are partially negatively charged. An electrostatic attraction results when two dipoles are brought together such that the positive end or pole of one molecule attracts the negative pole of another. This attractive force is what is called hydrogen bond. Fig 10.1 shows some examples of hydrogen bonds in molecules.

(a) Hydrogen bonds in HF (a) Hydrogen bonds in ice

Fig. 10.1 Hydrogen bonds in some molecules

In the crystal lattice of ice, each (H_2O) molecule is linked to the other by hydrogen bond. Alcohols (Alkanols) and some organic acid result from hydrogen bonds.

Step 2: Van der Waals forces

Van der waals forces are electrostatic attraction due to slight molecular dipoles, which are temporarily induced when molecules come into close contact. Van der Waals forces are found in solid iodine. The energy of van der waals' forces is usually about ten times less than that of hydrogen bonds.

Both van der Waals forces and the hydrogen bond are weak intermolecular bonds. Compound resulting from van der wals forces are often soft, volatile and lack conductivity. They have low melting and boiling points.

Evaluation: How much have you learnt?

Choose the options that answer the following questions correctly

1. In which of the following would you find hydrogen bond

   A. Ice

   B. Benzene

   C. H_2S0_4

   D. None of the above

2. Which of the following is not a strongly electronegative element

A. Oxygen

B. Nitrogen

C. Sodium

D. Fluorine

3. Van der waals forces and hydrogen bonds are both

A. strong bonds.

B. weak intermolecular bonds.

C. found in silver chloride.

D. none of the above.

4. In which of the following substances would you find van der waals forces?

A. Iodine

B. Sodium

C. Potassium

D. Calcium

Appendix B

Blueprint for Animation of Illustrations in Course of Study on Chemical Bonding (CSCB)

This is a guide for animating illustrations in *Course of Study on Chemical Bonding (CSCB)*, design and animation of electronic slides that run on computers, for the teaching of chemical bonding.

Step	Content	Fig No 1	Action on figure
1.	Identification of elements in the periodic table	Animate typical entry for potassium and hydrogen	On a click of the mouse, animation shows step by step procedures of entry of potassium and hydrogen in the periodic table. On the panels, the atomic symbols fly in first, followed by atomic numbers, and the relative atomic masses. Finally the Fig. caption.
2.	Names, symbols and atomic numbers of the first 20 elements	Animate Table 1.1, names, symbols and atomic numbers of the first 20 elements	On a click of the mouse, animation shows on a table first, the names of elements, followed by the symbols, and then the atomic numbers. All the **data** are to **fly into** the table, one after the other.
3.	The IUPAC periodic table	Animate Table 1.2, periodic table for the first 90 elements	On a click of the mouse, animation show first, the **period** and second, the **row**, with the arrows indicating their directions. On a click of the mouse, the entry of the elements appear one after the other, as in the table.
Lesson 2: Electronic configuration of the atom			
Step	Content	Fig No	Action on figure
1.	Bohr's model of the atom	Animate Bohr's model of the structure of the hydrogen atom (Fig 2.1)	On a click of the mouse, the atom appears, showing the nucleus and the election in their position. Next, on a click of the mouse, the electron moves on a circular orbit of a definite radius around the nucleus.
2.	The quantum mechanical model of the atom	Animate Fig 2.2, electron-density distribution	On click of the mouse, the nucleus of the atom appears in space. Next on a click of the mouse the x, y, z axis

			appear in position, with the nucleus at the centre or origin of the axis. Next, on a click of the mouse, the tick cloud appears around the nucleus followed by the light cloud indicating areas in the space within the atom where there is high probability of locating the electron.
Lesson 3 quantum numbers (Energy levels in the atom			
Step	Content	Fig No	Action on figure
1.	Main or principal energy shells in the atom	Animate Fig 3.1, main or principal energy shells in the atom.	On a click of the mouse, the main energy levels in the atom appear. On click of the mouse, the numbers and letters of the principal quantum energy shells appear.
2.	Spinning of electron about its axis	Animate Fig. 3.2 spinning of electron about its axis	On a click of the mouse, the electrons in a given shell spin in opposite direction, one east-west direction, the other west-east direction.
3.	Electron shells and sub shells in the atom	Animate fig 3.3, electron shells and sub shells in the atom.	On a click of the mouse, the K, L, M… shells appear. On a click of the mouse, the s, p, d, f sub-shells or orbitals appear.
4.	Energy levels in the atom	Animate Table 3.2, energy levels in the atom.	On a click of the mouse, the first row of the table appears, followed by the 2nd, 3rd and 4th rows in that order.
LESSON 4 Pauli Exclusion Principle			
1.	Shapes of the s and p-orbitals	Animate Fig. 4.1, shape of the s-orbital	On a click of the mouse, an outline of the shape of a sphere appears, and fades away and then the actual shape of the sphere appears and remains in position.
2.	Shapes of the p-orbitals	Animate Fig 4.2, shapes of the p-orbitals	On a click of the mouse, the x, y, z axes appear in space. Next, on a click of the mouse, the x-orbital appears along the x-axis, next, the y-orbital along the y-axis and z-orbital along the z-axis.
Lesson 5 The octet rule and Lewis structure			
1.	Lewis structure of Neon	Animate the Lewis structure of Neon (Ne)	On a click of the mouse, the symbol of Neon (Ne) appears. Next, on a click of the mouse, the electrons appear in pairs until an octet of electrons surround the **Ne** symbol.
2.	Lewis structure of chlorine	Animate the Lewis structure of chlorine (Cl)	On a click of the mouse, the symbol of chlorine (Cl) appears. Next, on a click of the mouse, the electrons appear in pairs; 3 pairs and 1 electron around the

			(Cl) symbol.
3.	Electronic configuration and Lewis symbol of some elements	Animate table 5.1, electronic configuration and Lewis symbol of some elements	On a click of the mouse, the various rows of the table appear one after the other in sequence, starting from row 1.
Lesson 6 Electronic configuration of the first 20 elements			
1.	Orbital diagram and the distribution of electrons in the atom	Animate Fig. 6.1, orbital diagram.	On a click of the mouse, the s, and p orbitals appear, arranged in a step-wise arrangement.
2.	Electron distribution in hydrogen	Animate Fig. 6.2, electron distribution in hydrogen	On a click of the mouse, the first row appears. On a click of mouse, the second row appears, showing the electron in the 1s-orbital.
3.	Electron distribution in helium	Animate Fig 6.3, electron distribution in helium	On a click of the mouse, the orbital energy level diagram appears, showing 2 electrons in the 1s orbital.
4.	Orbital energy level diagram of some elements	Animate Table 6.1, orbital energy level diagram of some elements	On a click of the mouse, the orbital energy level of individual elements in Table 6.1 appear in sequence, from lithium to neon.
5.	Electronic configuration of the atoms of the first 20 elements in the periodic table	Animate table 6.2, electronic configuration of the 1st 20 elements of the periodic table	On a click of the mouse, the various rows of the table appear, one after the other in sequence, starting from row 1.
Lesson 7 Types of bonds-Electrovalent (ionic) bond			
1.	Ionic bonding process	Animate Diagram 7.1, Formation of sodium ion	On a click of the mouse, the sodium atom appears, then loses an electron to become a sodium ion.
2.		Animate Diagram 7.2, Formation of chlorine ion	On a click of the mouse, the chlorine atom appears, then gains an electron to become a chlorine ion.
3.	Formation of sodium chloride	Animate Diagram 7.3, Formation of sodium chloride	On click of the mouse, the sodium and chlorine ions are attracted to each other (the ions move very close to each other) to form sodium chloride.
4.	Structure of sodium chloride	Animate Fig 7.1 structure of sodium chloride	On a click of the mouse, a crystal lattice of sodium chloride appears, moves about in space, displaying various parts of the structure.
5.	Formation of potassium sulphide	Animate Diagram 7.4. formation of potassium sulphide	On a click of the mouse, the sulphur ion and two potassium ions appear. On a click of the mouse, the sulphur ion and the two potassium ions move

			close to each other to form potassium sulphide.
6.	Formation of calcium chloride	Animate Diagram 7.5 formation of potassium sulphide	On a click of the mouse, one calcium ion appear and two chlorine ions appear. On a click of the mouse, the calcium ion and the two chlorine ions move close to each other to form calcium chloride.
Lesson 8 Covalent bonding			
1.	Formation of covalent bonds	Animate Fig. 8.1 overlap of electron orbitals Animate Fig. 8.2, Bonding in hydrogen	On a click of the mouse, the hydrogen atoms move, one in a clockwise direction and the other in anticlockwise direction, until their electron clouds overlap. On a click of the mouse, a *blinking* arrow appears, indicating the bond (area of overlap of the orbitals). See Fig 2.18. Bonding in hydrogen (p64, Chapt. 2).
2.	Bonding in clorine molecule	Animate fig 8.3	On a click of the mouse, two chlorine atoms with their electron clouds (in Lewis symbol) appear. On a click of the mouse, the atoms move close to each other until the clouds overlap. On a click of the mouse, a *blinking* arrow appears indicating the bond.
3.	Bonding in hydrogen fluoride	Animate Diagram 8.1 hydrogen fluoride	(Action steps as for bonding in chlorine molecule)
4.	Bonding in tetrachloromethane ccl_4	Animate Diagram 8.2, Tetrachloromethane (CCl_4	On a click of the mouse, one carbon atom (in Lewis symbol) and four chlorine atoms (in Lewis symbol) with their electron clouds appear and arrange themselves in space. On a click of the mouse, the atoms move closer to each other until the clouds overlap, forming bonds.
5.	Bonding in ammonia, NH_3	Animate Diagram 8.3, Ammonia (NH_3)	On a click of the mouse, one atom of nitrogen and 3 atoms of hydrogen (in Lewis symbol) appear and arrange themselves in space. On a click of the mouse, the atoms move closer to each other until bonds are formed.

6.	Representation of covalent	Animate diagrams 8.4 and 8.5	On a click of the mouse, the central atoms appear in space, next the atoms of the other elements appear in their position. On a click of the mouse, the lines appear joining the atoms of the different elements to the central atom.
	Lesson 9: Dative coordinate and metallic bonds		
1.	Formation of coordinate bonds in ammonium ion, NH_4^+	Animate Diagram 9.1, A reaction to form ammonium ion, NH_4^+	On a click of the mouse, ammonia (in Lewis symbol) and hydrogen ion (H^+) appear in space. On a click of the mouse, the chemical species move closer to each other; the arrow appears and the ammonium ion appears. On a click of the mouse, the ammonium ion structure appears showing its coordinate bond. The coordinate bond blinks.
2.	Reaction of ammonia with boron trifluoride.	Animate Diagram 9.2. Ammonia donates its lone pair electrons to boron trifluoride	On a click of the mouse, ammonia and boron trifluoride (in Lewis symbol) appear in space. On click of the mouse, the plus (+) and arrow ($\rightarrow$) appear in the equation. On a click of the mouse, the structure the new compound appears showing the coordinate bond.
3.	Metallic bond	Animate Fig. 9.1, structure of a metal	On a click of the mouse, a piece of metal appears; On a click of the mouse, the metal ions appears, embedded in a 'sea' of mobile electrons.
4.	Electronegativity and dipoles	Animate Diagram 9.3, Formation of hydrogen fluoride, HF	On a click of the mouse hydrogen and fluorine appear in space (in Lewis symbol, and electron cloud). On a click of the mouse, the chemical species move close to each other and bond. On a click of the mouse, the hydrogen fluoride molecule structure appears with the partial charges.
	Lesson 10 Hydrogen bond		
1.	Hydrogen bond	Animate Fig. 10.1(a), Hydrogen bond in HF.	On a click of the mouse, 4 molecules of HF, with

			their bonds and partial charges appear in space, and arrange themselves in position ready for attraction to one another. On a click of the mouse, *blinking* broken lines appear, linking the molecules, indicating the attraction of the molecules to one another.
2.		Animate Fig 10.1 (b) hydrogen bond in ice.	Follow the same steps as in Fig 10. (a) above.

Appendix C

CHEMICAL BONDING ACHIEVEMENT TEST (CBAT)

Time: 40 min

PART 1

1. Name of Student:---
2. Sex of Student:---
3. Age of Student:--
4. Name of school:---

Part 2

Instruction: Tick (√) the option you consider most appropriate answer in each question.

1. Which of the following pairs of elements in the periodic table would you expect to show the greatest similarity in chemical and physical properties?

A. He and P

B. Ca and Mg

C. B and F

D. Cl and O

2. To which group of elements does chlorine belong?

A. Halogen

B. Metalloid

C. Metal

D. Nobel gas

3. What group and in what period is the element Na located?

A. Group 1, Period 2

B. Group 2, Period 3

C. Group 3, Period 3

D. Group 1, Period 3

4. Which of the following elements is **not** an alkaline earth element?

A. Fe

B. Mg

C. Ca

D. Be

5. Which of the following is the electronic configuration of carbon atom?

A. $1s^2\ 2s^2\ p\ 2^3$

B. $1s^2\ 2s^2\ 2p^4$

C. $1s^2\ 2s^2\ 2p^2$

D. $1s^2\ 2s^2\ 2p^6$

6. Which of the following statements is true of elements in the same horizontal row of the periodic table?.

A. The number of electrons in the outermost shells of their atoms increase progressively from left to right.

B. The number of electrons in the outermost shells of their atoms decreases progressively from left to right.

C. The number of their valence shell electrons are equal.

D. They all have octet.

7. Which of the following names is given to the bond formed when an atom of a highly electronegative element combines with hydrogen?

A. Covalent bond

B. Hydrogen bond

C. Ionic bond

D. Ligand

8. What type of bond is found in sulphur molecule S_8 ?

A. Ionic bond

B. Van der waal's forces

C. Covalent bond

D. Co-ordinate bond.

9. Which of the following types of bond will be formed between water molecules and copper (II) ion?

A. Hydrogen bond.

B. Electrovalent bond.

C. Dative bond.

D. Covalent bond.

10. Which of the following compounds will dissolve in water?

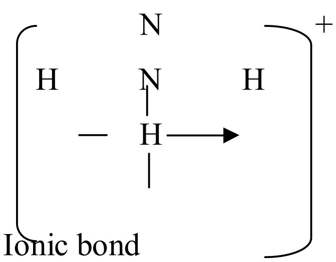
A. CH_4

B. CCl_4

C. NaCl

D. C_6H_6

11. In the structure below, what does the arrow ($\longrightarrow$) represent?



A. Ionic bond

B. Co-ordinate covalent bond

C. Metallic bond

D. Hydrogen bond

12. Which of the following statements is true about the strength of a metallic bond?

A. It increases with increase in number of valence electron.

B. It increases with increase in the size of atomic radius.

C. It increases with the height of the crystal.

D. It increases with the radius of cations.

13. Which of the following accounts for the high boiling point of water?

A. Water is a polar solvent.

B. Presence of covalent bond in water.

C. Presence of hydrogen bond in water.

D. Presence of dative bond in water.

14. Metals are able to conduct heat and electricity because of

A. The presence of free mobile electrons.

B. The presence of lone pair electrons.

C. The presence of mobile ions.

D. Their ability to form cations in the presence of heat and electric current.

15. The two main types of bond are.

A. Hydrogen and covalent bonds.

B. Electrovalent and covalent bonds.

C. Metallic and dative bonds.

D. Dative and covalent bonds..

16. How many lone pair electrons are present in ammonia molecule?

A. 6.
B. 2
C. 1
D. 4

17. Atoms combine chemically in order to

A. be strong.

B. form ions.

C. be stable.

D. be gaseous.

18. Gaseous diatomic nitrogen is a good example of a compound with

A. double covalent bond.

B. triple covalent bond.

C. single covalent bond.

D. double electrovalent bond.

19. Which of the following elements will have the highest tensile strength?

A. Na

B. Mg

C. Al

D. S

20. Which of the following statements is **not** correct about metallic bond?

A. It accounts for the ductility and malleability of metals.

B. Its strength increases with increase in the number of shells.

C. Its strength increases with increase in number of valence electrons.

D. It is the attraction between metallic ions and the electron cloud.

APPENDIX D

Software Rating Scale (SRS)

Instruction: Please evaluate this **Chemical Bonding Instructional Software Package (CBISP)** using the criteria provided for it. Please rate each of the criteria, by ticking (√) in the column that fits your assessment.

Key: Excellent = 4, Good =3, Fair =2, Poor =1

PART A

No	**Criteria for evaluation of Chemical Bonding Instructional Software Package**	Excellent	Good	Fair	Poor
1	Content information and grammar in Chemical Bonding Instructional Software Package (CBISP)				
2	Pedagogical approach in CBISP to content presentation for learning to take place.				
3	Ease of integration of CBISP into classroom use.				
4	User friendly of CBISP program				
5	CBISP content supports of the curriculum.				
6	Effectiveness of feedback message in CBISP				
7	Motivational features of CBISP program				
8	Ease of modification of CBISP program				
9	User control of CBISP program with regard to the rate and sequence or presentation.				
10	Clarity of statement and meeting of the objectives in CBISP program.				
11	Comprehensiveness and ease to understand teacher documentation in CBISP.				
12	Effectiveness of use of colour, sound, graphic and animation in CBISP.				
13	Freedom of CBISP program from technical errors.				
14	Freedom of CBISP program from content bias.				

PART B

Validated by (Name)--

Affiliation --

Highest Qualification /Rank--

Post Qualification Teaching Experience---

APPENDIX E

Inventory for Course of Study on Chemical Bonding (ICSCB)

Instruction: Please evaluate this Course of Study on Chemical Bonding (ICSCB) using the criteria provided for it. Please rate each of the criteria, by ticking (√) in the column that fits your assessment.

Key: Excellent = 4, Good =3, Fair =2, Poor =1

PART A

No	Criteria for evaluation of Course of Study on Chemical Bonding	Excellent	Good	Fair	Poor
1	**Content validity** Correctness of content information.				
	Appropriateness of language used, with regard to technical terms.				
	Suitability of language level used in communicating concepts to the grade of students for which the course was written. Adequacy and appropriateness of number of				
	illustrations and tables in the course work.				
2	**Curriculum congruence** Course work support of the curriculum				
3	**Content presentation** Pedagogical content presentation for learning to take place . Duration of lessons .				
4	**Lesson evaluation** Questions and activities provided for evaluation of the lessons .				

PART B

Validated by (Name) :--

Affiliation ---

Highest Qualification ---

Post Qualification Teaching Experience---

APPENDIX F

Calculation of the Reliability of Chemical Bonding Achievement Test (CBAT) using the Kuder-Richardson Formula 20

The Kuder-Richardson Formula 20 used to determine the reliability co-efficient of the instrument is of the form: r =

$$\left(\frac{n}{n-1}\right)\left(1-\frac{\Sigma pq}{st^2}\right)$$

Where r = the estimate of reliability.

N = the number of items in the test

St = the standard deviation of the test

Σ = summation of the n items

P= the percentage passing a particular item

q= the percentage failing the same item

The choice to use K-R formula 20 is informed by the fact that the responses entailed fail or pass, (wrong or right), that is, the responses are dichotomously scored. The calculation is shown below.

In the formula, r =

$$\left(\frac{n}{n-1}\right)\left(1-\frac{\Sigma pq}{st^2}\right)$$

n = 20 ;

st^2 = 20.4

S/N	p	q	Pq
1.	18 (0.86)	3 (0.14)	0.12
2.	18 (0.86)	3 (0.14)	0.12
3.	15 (0.71)	6 (0.29)	0.21
4.	19 (0.90)	2 (0.10)	0.10
5.	19 (0.90)	2 (0.10)	0.10
6.	16 (0.76)	5 (0.24)	0.20
7.	15 (0.71)	6 (0.29)	0.21
8.	11 (0.52)	10 (0.48)	0.25
9.	15 (0.71)	6 (0.29)	0.21
10.	20 (0.95)	1 (0.05)	0.05
11.	14 (0.67)	7 (0.33)	0.22
12.	13 (0.62)	8 (0.38)	0.24
13.	16 (0.76)	5 (0.24)	0.18
14.	4 (0.19)	17 (0.81)	0.15
15.	19 (0.90)	2 (0.10)	0.10
16.	15 (0.71)	6 (0.29)	0.21
17.	15 (0.71)	6 (0.29)	0.21
18.	15 (0.71)	6 (0.29)	0.21
19.	5 (0.71)	16 (0.76)	0.18
20.	6 (0.29)	15 (0.71)	0.21

$\sum pq = 3.46$

$$= \frac{20}{19}\left(\frac{20.4 - 3.46}{20.4}\right)$$

$$= \frac{20}{19}\left(1 - \frac{3.46}{20.4}\right)$$

$$= \frac{20}{19}(0.6960)$$

r = 0 .8740

r = 0.87

Appendix G

Reliability Co-efficient of the Items in CSCB instrument

The Cronbach's Alpha co-efficient (α) formula used in calculating reliability co-efficient of the items in CSCB is given by

$$\alpha = \left(\frac{n}{n-1}\right)\left(1 - \frac{\Sigma si^2}{sx^2}\right)$$

Where n=number of items in the test

Si =variance of a single item scores

Sx^2= variance of total item scores

Σ= Summation

Responses and Item Variances of Criteria for evaluation of Course of Study on Chemical Bonding (CSCB)

S/N	**Criteria for evaluation of Course of Study on Chemical Bonding (CSCB)**	Excellent	Good	Fair	Poor	Item Variance
1		4	3	2	1	0.25
	Content validity (i)Correctness of content information.	6	3	0	0	
	(ii)Appropriateness of language used, with regard to technical terms.	2	7	0	0	0.19
	(iii)Suitability of language level used in communicating concepts to the grade of students for which the course was written.	2	7	0	0	0.19
	(iv)Adequacy and appropriateness of number of illustrations and tables in the course work.	6	2	1	0	0.53
2	**Curriculum congruence** (v) Course work support of the curriculum	2	7	0	0	0.19
3	**Content presentation** (vi)Pedagogical content presentation for learning to take place	6	3	0	0	0.25
	(vii)Duration of lessons	4	4	1	0	0.50
4	**Lesson evaluation** **(viii)**Questions and activities provided for evaluation of the lessons .	6	1	1	1	1.2

$\Sigma s_i^2 = 3.3$

The respondents scores are: 31,31, 34, 34, 37, 37, 37, 37, 38.

Variance of respondents total item scores = 7.36

The Cronbach's Alpha co-efficient (α) formula used in calculating reliability co-efficient of the items in CSCB is given by

$$\alpha = \left(\frac{n}{n-1}\right)\left(1 - \frac{\Sigma si^2}{sx^2}\right)$$

Where n = number of items in the test

Si = variance of a single item scores

Sx^2 = variance of total item scores

Σ = Summation

n = 8;

ΣSi^2 = 3.3;

Sx^2 = 7.36

$$\alpha = \left(\frac{8}{7}\right)\left(1 - \frac{3.3}{7.36}\right)$$

$$= \frac{8}{7}(1 - 0.45)$$

$$= \frac{8}{7}(0.55)$$

= 0.63

Appendix H

Reliability Co-efficient of the Items in SRS instrument

The Cronbach's Alpha co-efficient (α) formula used in calculating reliability co-efficient of the items in **SRS** is given by

$$\alpha = \left(\frac{n}{n-1}\right)\left(1 - \frac{\Sigma si^2}{sx^2}\right)$$

Where n=number of items in the test

Si =variance of a single item scores

Sx^2= variance of total item scores

Σ= Summation

Responses and Item Variances of Criteria for evaluation of Chemical Bonding Instructional Software Package (CBISP)

S/N	**Criteria for evaluation of Chemical Bonding Instructional Software Package (CBISP)**	Excellent	Good	Fair	Poor	Item Variance
1	Content information and grammar in Chemical Bonding Instructional Software Package (CBISP).	4	3	2	1	0.00000
		4	0	0	0	
2	Pedagogical approach in CBISP to content presentation for learning to take place.	2	2	0	0	0.33333
3	Ease of integration of CBISP into classroom use	2	2	0	0	0.33333
4	User friendly of CBISP program	3	1	0	0	0.25000
5	CBISP content supports of the curriculum.	1	3	0	0	0.25000
6	Effectiveness of feedback message in CBISP	2	2	0	0	0.33333
7	Motivational features of CBISP program	2	2	0	0	0.33333
8	Ease of modification of CBISP program	0	4	0	0	0.00000
9	User control of CBISP program with regard to the rate and sequence or presentation.	2	2	0	0	0.33333
10	Clarity of statement and meeting of the objectives in CBISP program.	4	0	0	0	0.00000
11	Comprehensiveness and ease to understand teacher documentation in CBISP.	3	1	0	0	0.25000
12	Effectiveness of use of colour, sound, graphic and animation in CBISP.	0	4	0	0	0.00000
13	Freedom of CBESP program from technical errors.	0	3	1	0	0.25000
14	Freedom of CBESP program from content bias.	0	4	0	0	0.00000

$\Sigma s_i^2 = 2.6666$

The respondents scores are: 60, 65, 58, 64.

Variance of respondents total item scores =10.916666667

The Cronbach's alpha co-efficient (α) formula used in calculating reliability co-efficient of the items in SRS is given by

$$\alpha = \left(\frac{n}{n-1}\right)\left(1 - \frac{\Sigma si^2}{sx^2}\right)$$

Where n = number of items in the test

Si = variance of a single item scores

Sx^2 = variance of total item scores

Σ = Summation

n = 14;

ΣSi^2 = 2.666666665;

Sx^2 = 10.91666667

$$\alpha = \left(\frac{14}{13}\right)\left(1 - \frac{2.666666665}{10.91666667}\right)$$

$$= \left(\frac{14}{13}\right)(1 - 0.244274808)$$

$$= \left(\frac{14}{13}\right)(1 - 0.244274808)$$

= 0.813857899

= 0.81

Appendix I

Rating pattern of CBISP Quality by 4 teachers on SRS

Serial No. of Criteria for QualityEval-uation	Excellent(4) (100%)		Good(3)(75%)		Fair(2) (50%)		Poor(1) (25%)		Rating Score (X)	Remark
	No scoring	%	No scoring	%	No scoring	%	No scoring	%	%	
1	4	400							100	A
2	2	200	2	150					87.5	A
3	2	200	2	150					87.5	A
4	3	300	1	75					93.75	A
5	1	100	3	225					81.25	A
6	2	200	2	150					87.5	A
7	2	200	2	150					87.5	A
8			4	300					75	A
9	2	200	2	150					87.5	A
10	4	400							100	A
11	3	300	1	75					93.75	A
12			3	225	1	60			68.75	A
13			4	300					75	A
14			4	300					75	A

$\Sigma X = 1,200$; $\overline{X} = 85.71\%$

ΣX = Total Quality Rating score ; $\overline{X}$ = Mean Quality Rating score ; A = Accept

From this analysis, the CBESP was rated UHQ, which means above 75%.

APPENDIX J.

STUDENTS' INTEREST SCALE ON CHEMICAL BONDING (SISCB)

PART 1

Number of Student: ---

Age of Student: ---

Name of School: ---

Sex of student…………………………………………………………………

PART 2

Please tick (√) to indicate your level of agreement or disagreement with the following statements. Please be objective in your choice, there is no right or wrong answer.

Item	Statement	Statement category			
SN		SA	A	D	SD
1.	I feel happy each time I study chemical bonding process .				
2.	I enjoy working out the kind of bond in a chemical combination.				
3.	I feel happy when I demonstrate how chemical bonds are formed.				
4.	I spend my free time thinking about how bonds are formed in molecules.				
5.	I prefer to explain coordinate bonding to my classmates.				
6.	I feel excited during lessons on chemical bonding.				
7.	I appreciate anyone who helps me to understand how sharing of electrons by atoms is done.				
8.	I feel I understand chemical bonding easily when it is taught in class.				
9.	The use of charts in teaching chemical bonding lessons makes me to like chemistry more.				
10.	I do not like to think about hydrogen bonding.				
11.	For me, it easier to identify how many valence electrons are taking part in.				
12.	Without using chart, our teacher's explanation of hydrogen bonding bores me.				
13.	I feel on top of the world when I demonstrate to my classmates how positive and negative ions are formed in a chemical reaction				
14.	I feel bad each time I miss any lesson on chemical bonding.				

15.	For me, any demonstration of how chemical bonds are formed, is boring and confusing.				
16.	It is easy for me most times to identify the kind of chemical bond in a molecule.				

APPENDIX K

(A) ANSWERS TO EVALUATION QUESTIONS IN CSCB

Lesson →	1	2	**3**	4	5	6	7	8	9	10
Answers ↓ to questions	Introduction 1A 2D, 3A 1C 2A 3B 4C	1C 2D 3A 4B	1C 2A 3A 4C	1A 2A 3B 4A	1A 2A 3A 4C	1A 2A 3C 4D	1A 2C 3A 4B	1A 2B 3B 4A	1D 2A 3D 4A	1A 2C 3B 4A

(B) Answers to CBAT

1B	2A	3D	4A	5C	6A	7A	8B	9D
10A	11B	12A	13C	14A	15B	16C	17C	18B
19A	20B							

APPENDIX L

Data Analysis : SPSS for MS WINDOWS RELEASE 6.0

EUGENE OKORIE

17 Aug 13 SPSS for MS WINDOWS Release 6.0

- **- Description of Subpopulations - -**

Summaries of POSTACH Post achievement Score
By levels of METHOD Method

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population			0.9357	3.3053	311
METHOD	5.00	Experimental	9.3704	3.5067	162
METHOD	6.00	Control	8.4631	3.0124	149

Total Cases = 311

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Page 2

- **- Description of Subpopulations - -**

Summaries of POSTACH Post achievement Score
By levels of SEX Sex of the students

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population			8.9357	3.3053	311

SEX	1.00	Male	8.0230	2.9679	174
SEX	2.00	Female	10.0949	3.3582	137
Total Cases	=	311			

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- - Description of Subpopulations - -

Summaries of POSTACH Post achievement Score
By levels of LOCATION school Location

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population			8.9357	3.3053	311
LOCATION	3.00	Urban	8.7578	3.6409	128
LOCATION	4.00	Rural	9.0601	3.0530	183
Total Cases	=	311			

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- - Description of Subpopulations - -

Summaries of POSTACH Post achievement Score
By levels of SEX Sex of the students

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population			29.0579	14.6169	311
METHOD	5.00	Experimental	42.5864	5.0151	162
METHOD	6.00	Control	14.3490	1.4186	149

Total Cases	=	311

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- - Description of Subpopulations - -

Summaries of POSTINT Post achievement Score
By levels of SEX Sex of the students

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population			29.0579	14.6169	311
SEX	1.00	Male	28.6609	15.2991	174
SEX	2.00	Female	29.5620	13.7407	137
Total Cases	=	311			

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- - Description of Subpopulations - -

Summaries of POTINT Post achievement Score
By levels of LOCATIN Sex of the students

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population			29.0579	14.6169	311
LOCATN	3.00	Urban	31.7188	14.1025	128
LOCATN	4.00	Rural	27.1967	14.7199	183
Total Cases	=	311			

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* * * A N A L Y S I S   O F   V A R I A N C E * * *

	POSTACH	Post achievement Score
By	SEX	Sex of the students
	LOCATN	School location
	METHOD	Method
With	PREACH	Preachievement Score

UNIQUE sums of squares
All effects entered simultaneously

Source of Variation		Sum of Squares	DF	Mean Square	F	Sig of F
Covariates		153.628	1	153.628	28.952	.000
PRACH		153.628	1	153.628	28.952	.000
Main Effects		161.287	3	53.762	10.132	.000
SEX		17.151	1	17.151	3.232	.073
LOCATN		22.502	1	22.502	4.241	.040
METHOD		85.441	1	85.441	16.102	.000
2-Way Interactions		1202.698	3	400.899	75.551	.000
SEX	LOCATN	64.693	1	64.693	12.192	.001
SEX	METHOD	386.535	1	386.535	72.844	.000
LOCATN	METHOD	384.042	1	384.042	72.374	.000
Method x Gender x Location		5.970	1	5.970	1.092	. 297
Explained		1778.894	7	254.128	47.891	.000
Residual		1607.820	303	5.306		
Total		3392.684	311	10.925		

311 cases were processed.
0 cases (.0 pct) were missing.

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* * * A N A L Y S I S O F V A R I A N C E * * *

	POSTINT	Post interest Score
By	SEX	Sex of the students
	LOCATN	School Location
	METHOD	Method
With	PREINT	Pre-interest score

UNIQUE sums of squares
All effects entered simultaneously

Source of Variation		Sum of Squares	DF	Mean Square	F	Sig of F
Covariates		1.583	1	1.583	.117	.733
PREINT		1.583	1	1.583	.117	.733
Main Effects		48570.027	3	16190.009	1192.443	.000
SEX		40.510	1	40.510	2.984	.085
LOCATN		15.572	1	15.572	1.147	.0285
METHOD		37971.690	1	37971.690	2796.729	.000
2-Way Interactions		133.149	3	44.383	3.269	.022
SEX	LOCATN	4.973	1	4.973	.366	.545
SEX	METHOD	75.141	1	75.141	5.534	.019
LOCATN	METHOD	3.877	1	3.877	.286	.593

Method x Gender x Location	.326	1	.326	.037	.848
Explained	62119.073	7	8874.153	653.608	000
Residual	4113.885	303	13.577		
Total	66233.284	311	213.655		

311 cases were processed.
0 cases (.0 pct) were missing.

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APPENDIX M

TRAINING PROGRAMME FOR TEACHERS ON INSTRUCTIONAL SOFTWARE PACKAGE METHOD (ISM)

Introduction

This training is for you, the teacher to be conversant with your role in a teaching-learning process that involves the use of instructional software package. The software package essentially is for the students' use. However, in a classroom application, you as the classroom teacher, are expected to play some roles in students' learning.

Teacher's Roles when Using Instructional Software Package Method (ISPM) in the Classroom

Role 1. Before each lesson

I. Before the commencement of each lesson, ensure that the computers are in good working condition.
II. Boot the computer; thereafter insert the CD in the CD drive.
III. Click to open the folder to view the files.
IV. Select the CBISP; click to open lessons.
V. Listen to the instruction and follow it.
VI. Let students bring out their notepad or notebooks to take down points of interest in the course of the lesson.
VII. Select the lesson for the period, ask a student to click as may be directed by the computer.
VIII. Let the students interact with the computer and the learning material while you , the teacher watch.

Role 2. During each lesson

I. Draw students' attention to the objectives of the lesson.

II. Draw students' attention to particular aspects of the lesson, which they may need your help.

III. Explain aspects of the lesson as students may request of you.

Role 3. During evaluation of each lesson

I. Let students discuss among themselves their choice of options in the objective questions for evaluation.

II. Guide the students' discussion and ensure active participation of each student.

III. Offer students necessary aid to explain why certain questions are either right or wrong.

Role 4. At the end of each lesson

I. Click to close the file.

II. Remove the CD from the CD drive and keep CD safe for other lesson during the next chemistry period.

III. Shut down the computer.

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UNIVERSITY OF NIGERIA, NSUKKA

SCHOOL OF POSTGRADUATE STUDIES

SYNOPSIS OF Ph.D THESIS

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FACULTY	Education

YEAR OF GRADUATION 2014

PROPOSED TITLE OF THESIS Effects of Instructional Software Package on Students' Achievement and Interest in Chemical Bonding

SYNOPSIS

INTRODUCTION

The use of computer in 21st century learning is the common trend globally in pedagogy. Following this global trend in pedagogy, Nigerian secondary school chemistry curriculum recommended the use of computer in teaching chemistry concepts in schools. Literature points to the scarcity of relevant software packages and the need to develop them for computer-assisted instruction and learning, especially in chemistry where abstract and difficult concepts abound. One chemistry concept, as literature has shown, that students find difficult to learn is chemical bonding. Chemical bonding is at the heart of chemistry and a good understanding of the concept is fundamental to students' progress and achievement in chemistry. It became necessary to develop instructional software package for the teaching and learning of chemical bonding; and test its effects on students' interest and achievement in chemical bonding. The main purpose of this study was to determine the effects of instructional software package on students' achievement and interest in chemical bonding. Specifically, the study sought to (i) design and construct a chemical bonding instructional software package (CBISP), (ii) determine the effect of the use of CBISP on the students' interest in chemical bonding, (iii) determine the effect of CBISP on the mean achievement of students in chemical bonding, (iv) determine the interaction effect of method and students' gender on students' mean interest rating in chemical bonding, (v) determine the interaction effect of method and students' location on their mean interest rating in chemical bonding, (vi) determine the interaction effect of method and students' gender on their mean achievement in chemical bonding and (vii) determine the interaction effect of method and students' location on their mean achievement in chemical bonding.

METHODOLOGY

The design of the study was a quasi-experimental design. Specifically, pretest-posttest non-equivalent control group design was used. The study population consisted of 5,966 senior secondary class one (SS1) chemistry students in 57 senior secondary schools in Nsukka education zone of Enugu State, Nigeria. Purposive sampling technique was used for selection of schools, based on the following criteria: availability of ICT facilities such as computer and overhead projectors; ability of teachers to perform basic operations using the afore mentioned ICT facilities; school location (urban and rural) and gender of students. The sample consisted of 311 SS1 students drawn from selected sample of nine senior secondary schools in Nsukka education zone. Five of the schools made up of three urban-located schools and two rural-located schools constituted the experimental group; the control group consisted of four schools made up of two urban-located schools and two rural-located schools. The instruments for the study were Chemical Bonding Achievement Test (CBAT) and Students' Interest Scale in Chemical Bonding (SISCB). The SISCB was face validated. For the CBAT, in addition to face validation, content validation was carried out using a table of specification. The reliability of CBAT was 0.87, calculated using Kuder Richardson formula 20 and that of SISCB was 0.68, calculated using Cronbach alpha method. Regular chemistry teachers of the selected schools for experimental and control groups taught the students. The teachers for the control group used traditional lecture method (TLM) with course of study on chemical bonding (CSCB). The CSCB is a hardcopy and has the same text materials and illustrations as in the software. Intact classes were used. For the experimental group, treatment was teaching using instructional software method (ISM). The ISM involved guiding the students and making necessary explanations to them on request while learning, using the CBISP. Before treatment, the researcher administered CBAT and SISCB to the students as pre-tests. The students' scores in the tests were recorded and kept separately. Teaching followed the usual school timetable, as was peculiar to each school. On completion of the course content, the researcher administered CBAT and SISCB to the students as post-test and their scores were recorded separately. Data collected were presented, using descriptive statistics while twelve hypotheses were tested, using analysis of covariance (ANCOVA) at 0.05 level of significance.

RESULTS

Mean achievement score of experimental group (9.37) was higher than that of the control group (8.46). Mean achievement score of female students (10.09) was higher than that (8.02) scored by male students. Rural students' mean achievement score (9.10) in chemical bonding was higher than that of urban students (8.76). Method of teaching had significant effect on students' mean achievement score in chemical bonding

($p < 0.05$). Gender had no significant influence ($p > 0.05$) on students' mean achievement score in chemical bonding. School location had significant influence ($p < 0.05$) on students' mean achievement in chemical bonding. The interaction effect of gender and location on students' achievement in chemical bonding was significant ($p < 0.05$). The interaction effect of gender and teaching methods on students' achievement in chemical bonding was significant ($p < 0.05$). The interaction effect of location and teaching methods on students' achievement in chemical bonding was significant ($p < 0.05$). Mean interest score (42.60) of experimental group on chemical bonding was higher than that (14.34) scored by the control group. Female students' mean interest score (29.60) on chemical bonding was higher than that (28.70) scored by male students. Mean interest score (31.72) of urban students on chemical bonding was higher than that (27.20) scored by rural students. Gender had no significant influence ($p > 0.05$) on students' interest in chemical bonding. School location had no significant influence ($p > 0.05$) on students' interest in chemical bonding. Method of teaching had significant effect ($p < 0.05$) on students' interest in chemical bonding. The interaction effect of gender and school location on students' interest in chemical bonding was not significant ($p > 0.05$). The interaction effect of gender and teaching methods on students' interest in chemical bonding was significant ($p < 0.05$). The interaction effect of school location and teaching methods on students' interest in chemical bonding was not significant ($p > 0.05$).

APPENDIX N

Lists of Schools Involved in the Study

1. Boys Secondary School, Ibagwa-Aka
2. Boys Secondary School, Ovoko
3. Girls Secondary School, Iheaka
4. Girls Secondary School, Opi
5. Government Technical College, Nsukka
6. Nsukka High School, Nsukka
7. Saint Cyprian’s Special Science School, Nsukka
8. Saint Theresa’s College, Nsukka
9. Urban Girls Secondary School, Nsukka