CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Science is an organised body of knowledge that uses a systematic approach in exploring or investigating nature in a testable and verifiable manner in order to establish presumed relations among phenomena with the basic aim of improving our understanding of nature. Okebukola (2008) has identified the major components that science should reflect and these are: information domain, process domain, creative domain, attitudinal domain and personal relevance domain. Science is one of the core components of the school curriculum and it includes separate subjects like Physics, Chemistry and Biology in secondary school. These are referred to as natural science. The learning of any science therefore, should emphasise the nature of science as a dynamic discipline in which inquiry is central. An inquiry-based learning approach is an activity-oriented that enables learners to explore the environment and use the process skills of observing, collecting, measuring, analysing, predicting and interpreting to construct knowledge, reflect and apply the knowledge to solve problems in the environment. Engaging students in scientific inquiry activities promotes their acquisition of scientific knowledge and science process skills (Ajeyalemi, 2011; Yager & Akcay, 2010).

Globally, science and technology are changing the world around us at an unbelievable rate. Any nation that ignores scientific and technological education may find it difficult to fit into the global advancement in science and technology. In the years past, learning in classrooms was a cycle of memorisation, repetition and note copying but now, the world is increasingly shaped by Information and Communication Technology (ICT). Technology has become an integral part of everyday living at home and school, learners come in contact with the mobile phone, Ipad, television, computer, internet, games, automatic doors, security cameras, remote control, fax machines and many others. A conflict then arises when such students get to the classroom and are still expected to listen, write and regurgitate (Aladejana, 2007). Thus, the 21st century classroom must be matched with the 21st century education which should be flexible, creative, challenging and complex.

The state of science teaching and learning in Nigeria is a concern to all. According to Aladejana (2007), science teaching at various levels still retains the old conservative approach with the teacher, in most cases, acting as the repertoire of knowledge and the students as the passive recipients. In a conventional lecture-based teaching environment, students' involvement is restricted as teachers usually employ teaching methods which focus on information delivery and knowledge acquisition rather than encourage the construction of knowledge within the social context. Most of the time, the conventional lecture is conducted through a one-way communication, with limited opportunities for class discussion and active student involvement. Studies confirmed that traditional science teaching still rely heavily on lectures, reading and teacher demonstrations in a typical Nigerian science classroom setting where expository and unproductive teaching methods are often observed (Agogo & Onda, 2014; Ajeyalemi, 2011; Ikeobi, 2004;). These teaching strategies are said to be inadequate and inappropriate to attain conceptual learning and critical thinking (Adesoji & Raimi, 2004; Opara, 2009). The predominant use of teacher-centred teaching methods in which the teacher acts as the custodian and dispenser of knowledge and students as receptors makes students passive listeners, taking notes from projected displays and from the lecturer's explanations (Talib, 2005). Understanding the concept becomes difficult especially where the concept is not only complex, but also abstract and dynamic as in chemistry in particular.

Udeani (1992) as cited by Adeoye (2016) reported that classroom interaction accounted for about 74% and 71% of variation in students' cognitive achievement and process skills acquisition respectively. Ikeobi (2004) stressed that meaningful learning is possible in science if the students are given opportunities to operate equipment and materials that help them to construct knowledge of phenomena and related scientific concepts. Furthermore, Ajeyalemi (2011) emphasized the importance of engaging science students in practical activities. Students are active participants and need to be engaged in the learning process.

Chemistry, the science subject that deals with the composition, structures and properties of matter also deals with the interactions between different types of matter and the relationships between matter and energy. Through the learning of chemistry, it is possible to acquire relevant conceptual and procedural knowledge as well as develop understanding and appreciation of development in engineering, medicine and other related scientific and technological fields. Furthermore, learning about the contributions, issues and problems related to innovations in chemistry will help students to develop a holistic view of the relationships among science, technology and society. As numerous as the importance of chemistry are, students encounter difficulties learning the subject because of the abstract nature of the subject which has been confirmed by many authors (Kousathana & Tsaparlis, 2002; Raviolo & Garritz, 2008). In addition, conceptual and procedural difficulties are also associated with the subject (BouJaoude & Barakat, 2000; Chandrasegaran, Treagust, Waldrip & Chandrasegaran, 2009).

Knowledge comprises ideas, facts, principles and theories possessed by an individual about an object or phenomenon that is obtained through experience. Conceptual knowledge is made up of the constructed, integrated and functional ideas, facts and principles in a subject area that is in the learner's cognitive structure. It may be achieved through instruction and by thoughtful and reflective mental activity that is devoid of any memorization. Knowledge that is mentally organized and meaningfully learnt facilitates appropriate retrieval and application in solving problems in a particular knowledge domain. Thus, learning with understanding (meaningful learning) is more powerful than memorization because such organization improves retention and facilitates learning of related materials (Naiz, 1998; Naiz and Chacon, 2003; Niaz, 2005).

Taber (2001) argued that, unlike Physics and Biology, Chemistry does not allow for ease of constructing naïve meanings related to real world phenomena. Evidence abounds that learners have difficulties in learning the subject (WAEC 2005, 2007, 2011; Acar & Tarhan, 2007; Opara, 2009). Students have great difficulty understanding chemistry concepts at all levels of education (Berg 2012). This may be due to the ideas students bring to the study of chemistry which have been formed from their experience of the world and which differ from accepted scientific ideas (Mulford & Robinson, 2002). The performance in external examination is an indication that students have difficulty learning the subject.

Analysis of students' performance in Chemistry in WASCE from 2006 to 2014 showed that the performance of students in chemistry in most cases was less than 50% except in 2010, 2013 and 2014 where more than 50% credit pass was recorded which was inconsistent. This is an indication that students may have some learning difficulties in the subject. The candidates' weaknesses identified by The Chief Examiners' were:

> *"Poor level of communication skills, inadequate practical exposure, poor quantitative skills, inability to relate concepts in Chemistry to everyday life and lack of understanding of some Chemistry concepts"* (WAEC, 2006 - 2012).

This phenomenon has also been observed internationally (Acar & Tarhan, 2007; Anthony, 2009). Many reasons have been adduced for this poor performance in chemistry. According to Samba and Eriba (2012), it may be due to the abstract nature of chemistry concepts while Mailumo, Agogo and Kpagh (2007) hinged it on student and teacher related factors. Part of the teacher related factors is the teaching methods employed by teachers to teach the concepts.

Further analysis of the results showed that students find certain topics difficult to learn in Chemistry. Different authors (Opara, 2009; Ajeyalemi, 2011 and WAEC, 2011; 2012; 2013) have attributed the learning difficulties to the abstract nature of many Chemistry concepts, didactic methods of instruction, students' levels of conceptual understanding, mathematical abilities, problem solving skills among other factors that may be responsible for this poor performance.

Conceptual understanding in chemistry is the constant interplay between the macroscopic, microscopic and symbolic levels of thought and it is the act of understanding of the concepts that represents a significant challenge to the novice (Bradley & Brand, 1985). Three levels of understanding of concepts (the macroscopic, microscopic and symbolic levels) have been identified in education, particularly in learning chemistry (Anderson, 1990; Johnstone, 1993 and Gabel, 1993). The macroscopic level is a concrete level of understanding which corresponds to knowledge acquired through observing objects such as physical properties of an object and change in states of matter. The microscopic level is an abstract level but corresponding to observable phenomena at the macroscopic level. This level is characterised by concepts, theories and principles used to explain what is observed at the macroscopic level. Examples are movement of electrons, molecules or atoms. The symbolic level is used to represent macroscopic and microscopic phenomena by the use of chemical symbols, formulae, numbers, chemical equations, mathematical equations, graphs and representation of reaction mechanisms. For learning to be effective, the concepts ought to be understood meaningfully at all levels. Chemistry teachers and students are expected to operate across all the three levels of thought easily and move from one mode of thinking to the other (Gabel, 1993; Johnstone, 1993; Bowen & Bunce 1997 and Treagust, Chittleborough & Mamiala, 2003). Johnstone (1993) placed these three levels at the vertices of a triangle and emphasised that "every student studying chemistry for whatsoever purpose needs to operate within the triangle".

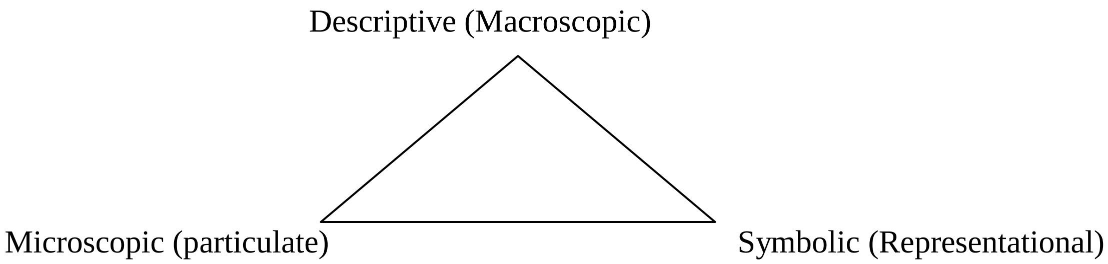


Figure 1.1: Levels of knowledge representation.

It has been shown that the skills in translating among the representations are often limited among chemistry students because their understanding is confined to the surface features of a representation at the macroscopic level such as colour, density appearance and all physical properties (Bowen & Bunce, 1997; Kozina & Russel, 1997; Treagust, Chittleborough & Mamiala, 2003). Students therefore have difficulties in understanding concepts at the microscopic and symbolic levels and in integrating mentally across the three levels.

In general, the difficulties that students at all levels of education encounter in understanding chemical concepts can be summarised as follows: inadequate conceptual knowledge, inability to interrelate the content representation at macroscopic, microscopic and symbolic levels as well asthe unobservable particulate and mathematical nature of chemistry content (Gabel, 1999; Kelly, Phelps & Sanger, 2004; Stain & Talanquer, 2008; Tsoi, Goh & Chia, 2010). However, the most prevalent studies on students' understanding in chemistry are on the identification of their misconceptions and correct conceptions on certain chemistry topics. There exists few studies on students' understanding at the three levels of thought (macroscopic, microscopic and symbolic) either in relation to the students' levels of thought (Sanger & Phelps, 2007), ability to solve quantitative problems (Kelly & Jones, 2008) and acquisition of skills or attitude to chemistry learning (Gilbert & Treagust, 2009; Omilani, 2010). All these contributed to some topics being labelled as difficult.

Literature abounds on the difficult topics and concepts in chemistry. For example, the most frequently reported difficult topics in Chemistry as revealed by WAEC Chief Examiners and in Science Education literature are Electrolysis, Redox Reactions, Chemical Kinetics and Chemical Equilibrium (Adesoji, 1992; Adigwe, 1993; Ozkaya, Uce & Sahin, 2003; Quilex, 2007; Raviolo & Garritz 2009; WAEC, 2006; 2007; 2008; 2009). Other reported difficult topics and concepts include the Mole Concept (Adesoji, 2004; Ellis, 2009) and Organic Chemistry (Szu, Nandagopal, Shavelson, Lopez, Penn, Scharbergs, & Hill, 2011; Flynn 2011).

Lack of problem-solving skills is another factor responsible for the difficulty students encounter in chemistry. The ability of students to solve numerical problems is not equivalent to conceptual understanding of molecular concepts. In addition, teaching students to solve problems is not equivalent to teaching concepts. Though students have conceptual difficulties, many of them are still able to solve quantitative problems related to the domain correctly. They do this by relying on algorithms especially for basic or routine problems (Gabel, Sherwood & Enochs, 1994; Gabel & Bunce, 1994). It then becomes difficult for students to solve problems that are ill-defined and do not have a set of steps by which to move through the problem. Therefore, problem solving skills need to be developed in students as a result of learning. Research studies have shown that methods of teaching enhance the acquisition of problem-solving skills. Therefore, the teaching method employed by the teacher is an important factor to be considered.

The use of teacher–centred methods of teaching which do not allow for students' involvement has been attributed to be the major cause of students' learning difficulties in chemistry (Aladejana, 2011; Aladejana & Idowu, 2006; Talib, 2005). Obzori (2011) referred to these methods of teaching where students are passive and which generate non-meaningful learning as "Transmissive teaching". "Transmissive teaching" leads to rote memorisation of the knowledge acquired which is not truly assimilated by the students and does not translate into applicable skills. Obzori (2011) argued that transmissive methods of teaching lack overall understanding of the contents; connections and comparisons are overlooked and the student struggles with discussing what he or she has learned in an order different from that which he/she has studied. In other words, knowledge is memorized but it is meaningless and does not translate into thought. This problem could be solved through appropriate teaching methods.

The new curricula in most countries often recommend to varying degrees, a transition from a "teacher-centred classroom" to a "student-centred learning environment." Science, by nature, is systematic, testable and its processes can be replicated and this justifies the fact that science should be taught by doing. The teacher should not spend a great deal of time telling students about science; instead students should be provided with opportunities to find out on their own. There is pure discovery learning approach where the learner is left to discover by himself without any assistance or guidance and where the learning is not structured. An alternative teaching approach for the development of intellectual skills and critical thinking is the guided discovery method (FME, 1985). This has been recommended as the appropriate instructional strategy by the developers of science curricula and chemistry curriculum in particular.

Discovery learning is much older than imagined. Jean Jacquis Rousseau (1712-1778) in his philosophical writings had proposed that children should not be taught directly but should be allowed to discover things for themselves especially through play and that learning how to learn was of much greater importance than teaching factual information. Teaching was to be restricted to posing questions for the student to answer and to creating situations to facilitate discovery by the student (Anula, 2006). When discovery is guided, it is a student-centered, activity- oriented teaching strategy in which the teacher guides the students through problem solving approach to meaningfully learn the instructional topics at hand (Abdullahi, 2007). Then it is called guided discovery, the recommended method for science teaching in Nigeria (FME, 2014). According to Akinsete (2006), it is a method of teaching that encourages a child to solve problems by seeking and asking questions as to gather information.

Guided discovery involves creativity and students' participation in a well equipped learning environment. Akinsete, (2006) also noted that this method of teaching helps students' conceptualisation and understanding of science concepts. The guided discovery approach is a form of inquiry which involves finding unknown concepts through the use of process skills. The instructor devises a series of statements or questions or activities that guide the learners step by step, making a series of discoveries that lead to a single predetermined goal. In other words, the instructor initiates a stimulus and the learner reacts by engaging in active inquiry thereby discovering the appropriate response (Kirschner, Sweller & Clark, 2006). However, the guided discovery, as a recommended approach of teaching science, is faced with some challenges in Nigeria because of the present school structure in terms of class sizes, curriculum content, grade levels and standardised tests (Akinsete, 2006). All these challenges make it difficult for teachers to employ the guided discovery teaching method in the classroom.

The teaching method often employed in science teaching in Nigeria which though, teacher-centred, yet may encourage inquiry to some extent, is the teacher-demonstration method. Instead of science teachers using the curriculum recommended guided discovery approach, most of them resort to teacher demonstration. The demonstration method is a teaching strategy that involves a demonstration being carried out by the teacher for students to observe/participate in or by the student for both the teacher and other students to observe/participate. Although, it emphasises the demonstrator's activities and reduces those of the students at the same time yet demonstration is desirable and necessary where dangerous or complex procedures are involved, where apparatus is complicated and expensive and where equipment are limited. In using the method, the demonstrator may explain steps in an operation, techniques of handling a piece of apparatus or the procedure in carrying out an activity. The method, being activity-oriented, is executed with examples to enhance cognitive, affective and psychomotor domains of instructional objectives. Demonstration also appeals to the students' sense of sight and hearing and could be presented to the entire class, small group of students or to an individual student. According to Nwachukwu & Nwosu (2007), the teacher can promote maximally the gains of demonstration method through conscious manipulation of classroom interactions. These classroom interactions include stating instructional objectives, planned repetition, active students' involvement, reinforcement and questioning. It is the effectiveness of manipulation of classroom interactions that helps the students to achieve more of the educational objectives. Nwachukwu & Nwosu (2007) argued that the demonstration method can promote educational objectives as it can be applied at different levels of instructional objectives if well planned by the teacher. The major criticism against the teacher demonstration approach is that it does not usually involve students' active participation in the process because it is teacher-centred. This disadvantage of teacher demonstration makes a strong point for the adoption of the guided discovery teaching method.

The shift from teacher-centred teaching approach to students' active participation strategies has led to the inclusion of technology in the classroom like never before. Technology tools such as computers, mobile learning devices, software applications, video, audio, multimedia, and information communication technology are being integrated into the classrooms. The integration of such tools has contributed to efficiency and effectiveness of teaching and learning. The reasonable use of Information Technology (IT) makes scientific teaching methods more effective, flexible and multiple (Dawson,Faster, & Reid, 2006). The application of IT in the classroom enables teachers to stimulate students' learning and challenge their higher order thinking skills. Students are more of visual learners; therefore, appropriately designed software materials can help students build mental links to strengthen their logical framework of conceptual understanding and to achieve a mastery level in learning of chemical concepts (Arasasingham, Taagepera, Potter, Martorell & Lonjers, 2005). Talib, Matthews & Secombe (2005) proposed the integration of software as an effective teaching strategy to promote effective conceptual change in electrochemistry. Also, Oyelekan & Olorundare (2009) supported the fact that computer instructional package software improved senior secondary school students' performance in electrochemistry. However, it seems that the integration of ICT into classroom practice by chemistry teachers around the world is a bit slow and some barriers to integrating ICT use in the schools' curriculum have been identified (BECTA, 2004).

This study therefore orchestrated the timely use of Information Technology-integrated teaching strategies without further delay.

1.2 Statement of the Problem

The importance of Chemistry in the society today cannot be over emphasised because of its relationship to other fields. The knowledge of the subject and its applications contribute immensely to industrial development of any nation. As numerous as the importance of chemistry, students encounter difficulties learning the subject especially at the secondary school level because of its abstract nature. These learning difficulties include consistent poor conceptual understanding and problem solving ability which might have been responsible for Nigerian students' consistent poor performances in the subject in the external examinations conducted by the West African Examinations Council (WAEC) as well as the consistent poor conceptual understanding and inability to relate concepts in Chemistry to everyday life as reported by the Chief Examiners.

The observed students' poor performance and weaknesses in chemistry in Nigeria is a strong indication of students' poor conceptual knowledge and inadequate skills acquisition which might have been caused by the teaching methods often employed by the chemistry teachers. Teaching methods employed by chemistry teachers in Nigeria do not match with the needs of the 21st century learners, as they encourage rote memorisation that leads to poor meaningful learning at the macroscopic level. Guided discovery approach was recommended for science teaching because it is activity oriented and involves active students' participation. However, the most commonly used methods are the lecture and the teacher demonstration methods where students are often passive learners. Hence, students find some topics difficult to learn in chemistry.

Could the integration of IT into strategies of teaching improve students' performance and reduce learning difficulties in some chemistry difficult topics? This study therefore, investigated if the teaching and learning of chemistry would be improved by integrating computer interactive instructional activities into the recommended teaching strategy – guided discovery approach and the commonly used teacher demonstration method for teaching some of the difficult topics in chemistry. The study also sought to determine the relative effectiveness of the two different teaching strategies on students' learning outcomes in chemistry.

1.3 Purpose of the study

The purpose of this study was to integrate Information Technology (IT) into two strategies of teaching and determine their effectiveness on the teaching of some difficult topics in chemistry. The relative effectiveness of the two teaching strategies namely, IT-Integrated teacher demonstration strategy (ITD) and IT-Integrated guided discovery strategy (IGD) on four chemistry students' learning outcomes (conceptual understanding, problem-solving skills, acquisition of basic science process skills and 21st century skills) in four randomly selected difficult topics in senior secondary school chemistry was then determined.

The specific objectives of the study were to:

(1) examine the effect of each of the treatments (IT-Integrated teacher demonstration strategy and IT-Integrated guided discovery strategy) on students' learning outcomes (conceptual understanding; problem-solving skills; acquisition of basic science process skills; and acquisition of 21st century skills) in four difficult chemistry topics.

(2) determine the influence of school type on the students' learning outcomes in chemistry when taught with the two teaching strategies.

(3) determine if gender has any influence on the students' learning outcomes in chemistry using the two teaching strategies.

(4) determine the interaction effects of treatment and school type on the students' learning outcomes in chemistry.

(5) determine the interaction effects of treatment and gender on the students' learning outcomes in chemistry.

(6) determine the interaction effects of school type and gender on the students' learning outcomes in chemistry

(7) examine the interaction effects of treatments, gender and school type on the students' learning outcomes in chemistry.

1.4 Research Questions

(1) What are the effects of treatments (IT-Integrated teacher demonstration strategy and IT-Integrated guided discovery strategy, Guided discovery and Teacher demonstration) on students' learning outcomes (conceptual understanding; problem-

solving skills; acquisition of basic science process skills; and acquisition of 21st century skills) in chemistry?

(2) How does school type influence the students' learning outcomes in chemistry?

(3) What is the influence of gender on students' learning outcomes in chemistry?

(4) How do the treatments interact with school type to affect chemistry students' learning outcomes?

(5) To what extent do the treatments interact with gender to affect chemistry students' learning outcomes in chemistry?

(6) What is the interaction influence of school type and gender on students' learning outcomes in chemistry?

(7) What is the interaction influence of treatments, gender and school type on students' learning outcomes in chemistry?

1.5 Null Hypotheses

The following null hypotheses were tested at 0.05 level of significance in the study

$H_0$1: There is no significant main effects of treatments (IT-Integrated Guided Discovery, IT-Integrated Teacher Demonstration, Guided discovery and Teacher demonstration) on the students' learning outcomes (conceptual understanding; problem-solving skills; acquisition of basic science process skills; and acquisition of 21st century skills) in chemistry.

$H_0$2: There is no significant influence of school type on the students' learning outcomes in chemistry.

$H_0$3: There is no significant influence of gender on the students' learning outcomes in chemistry.

$H_0$4: There is no significant interaction effects of treatments and school type on the students' learning outcomes in chemistry.

$H_0 5$: There is no significant interaction effects of treatments and gender on the students' learning outcomes in chemistry.

$H_0 6$: There is no significant interaction effects of school type and gender on the students' learning outcomes in chemistry.

$H_0 7$: There is no significant interaction effects of treatments, gender and school type on the students' learning outcomes in chemistry.

1.6 Significance of the study

The results of this study would be of immense benefits:-

(i) To the chemistry teachers; the findings of the study would provide empirical evidence that integrating computer interactive instructional package into instructions would foster acquisition of scientific knowledge, skills and appropriate attitude towards the difficult topics and this may be extrapolated to the less difficult topics.

(ii) To the students; chemistry students would find great assistance in acquiring meaningful understanding of abstract chemical processes and concepts such as redox reactions, mole concept, electrolysis and many others in the IT-integrated strategies with learning activities that complement each other in simulations and animations as this may improve students' performance in external examinations.

(iii) The findings from this study would contribute to knowledge about teaching and learning strategies that use computer interactive packages in classroom environment to address teaching difficulties in abstract and difficult concepts in chemistry.

(iv) The findings of the study would inform curriculum developers, science educators and chemistry teachers on the need to integrate the use of computer interactive instructional packages into instructional materials for teaching and learning of science in Nigeria according to global standards in this era of e–learning. Thus, the teachers would be better equipped for effective delivery.

(v) The interactive instructional packages developed could be adapted for use in other topics or subjects by other teachers and researchers.

1.7 Scope and Delimitations of the Study

The study was limited to chemistry students in senior secondary school (SSS) II in some public and private secondary schools from two Educational Districts in Lagos State. The concepts covered were four difficult topics in the senior secondary school chemistry curriculum: the mole concept, electrolysis, rates of chemical reactions and oxidation and reduction reactions (redox reaction). IT-Integrated Guided Discovery, IT-Integrated Teacher Demonstration, Guided discovery and Teacher demonstration were the teaching strategies used to teach the selected topics.

1.8 Theoretical Framework

The study was based on the Constructivist Learning Theory.

1.8.1 Constructivism

Constructivism is based on the theory that learners construct knowledge individually (and socially) to achieve meaning while they learn as advocated by Dewey, Bruner, Piaget, Vysgostsky and other protagonists of this approach. Constructivism as a cognitive paradigm views learning as an active, contextualised process of constructing knowledge rather than acquiring knowledge based on only personal experiences of the environment.

The Nigerian secondary school students are familiar with different modern means of Information technology (IT) by virtue of their school as well as home environments. The IT tools they are familiar with include; personal computers, IPADs, IPODs. Phones, software and many others. Many of them use their knowledge of computer to access e-mail, social networking sites and to surf the internet generally. All the above could be related to different learning theories. The study is mainly based on the principles of learning through the use of multimedia constructivist learning environments. However, this study was anchored on the two learner-centred theories.

1. Jerome Brunner's Social Constructivism (1990)
2. George Siemens's Theory of Connectivism (2005)

Jerome Brunner's Social Constructivism (1990)

This theory was propounded by Jerome Brunner (1990), it focussed on the actual classroom practices and the use of IT that involves teacher as facilitator and the learners as the main centre of interest. According to Brunner (1990), invention or creativity is the process of coming up with new knowledge on the basis of learners' experience. In this theory, the learner used the knowledge he/she already acquired to get new knowledge through the facilitator who is the teacher. The theory perceives knowledge as something that emanates from the learner. Brunner (1990) recommends that new knowledge may be found from that which one knows without changing its structure. The student uses his/her experience or the previous information learned to construct new ideas or knowledge. The learner participates in all the learning activities that determine his/her performance.

Social constructivists recognise substantial interactions with materials and resources and encourage 'hands-on activities above all as well as 'minds-on activities'. Constructivists recognised that knowledge is constructed by each learner through his or her engagement with the physical and social environments. Jerome Bruner focused on Technology, particularly multimedia which offer a vast array of such opportunities. Visualisation strategies of multimedia learning environments provide information in multiple ways so that students are able to construct their own knowledge; improve learning by developing strong mental models that are rich in multiple perspectives of chemistry concepts; examined how students process information from multiple representations to develop their own understanding in animations and simulations presented in multimedia learning environment. The learning environment should be designed in such a way as to support and challenge learner's thinking. According to Dick, Carey & Carey (2005) constructivism has had a major impact on the thinking of many instructional designers. For example, it has been widely used in designing IT instructions.

Jerome Brunner's Social Constructivism highlighted that:

- The explanation proffered must be thoroughly convincing to make the students discard their old ideas about poor perceptions of the subject (Chemistry) as being difficult as well as to make them dissatisfied with their prior conceptions.
- The knowledge must be intelligible and sound believable.
- Students should be engaged in the tasks that could make them apply their knowledge.
- Students should be encouraged to reflect on the newly acquired knowledge by the use of feedback activities.

Social Constructivism theory is applicable to this study because students are encouraged to solve problems on their own in the Information Technology-integrated strategies (ITD and IGD).

In the IT-integrated strategies, the difficult topics taught were selected from the Nigerian Senior Secondary School Chemistry Curriculum (NERDC, 2007) and these have been programmed and stored in the CD-Rom to give direction during interaction. The student uses his/her computer knowledge to receive messages which enhances interaction. Students were also encouraged to understand the difficult concepts by using animations and simulations provided in the packages to be involved in activities that lead to the right direction. Activating students' prior knowledge of computer literacy and purposefully connecting contents of difficult topics in Chemistry is extremely important and was integrated within this framework. Activities were organised in the developed IT-integrated packages following the principles of each strategy (Teacher demonstration and Guided discovery) so that the students continually built upon what they have already learned. This view has profound implications for teaching difficult topics in chemistry as it suggests a far more active role for students in their own learning than is typical in many traditional chemistry classrooms. In teaching, the approaches used by teachers contribute greatly to the outcome of the learners in class and outside the class in everyday living. Therefore, the responsibility of the teacher is to ensure that learners get knowledge by incorporating new approaches such as IT-integrated strategies in their teaching so as to improve students' performance in the subject.

George Siemens's Theory of Connectivism (2005)

This theory was used to explain the effect of technology on how humans live, communicate and learn. It combines the relevant elements of many learning theories, social structures and technology to create a powerful theoretical construct for learning in the digital age (Perrin, 2005). This theory makes use of a network with nodes and connections as a central metaphor for learning. A node could be information, data, feelings and images that can be connected to another node to make meaning. According to Siemens (2005):

> '*Learning is a process that occurs within nebulous environments of shifting core elements- not entirely under the control of the individual. This learning that is defined as actionable knowledge which can reside outside of humans within an organisation or a database, is focussed on connecting specialised information sets and connections that enable humans to learn more are more important than the current state of knowing' (p.4).*

Some of the principles of connectivism identified by Siemens are:

- Learning may reside in non-human appliances.
- Learning is a process of connecting specialised nodes or information sources
- Currency (accurate, up-to-date knowledge) is the intent of all connectivist learning activities.

- Decision-making is itself a learning process. Choosing what to learn and the meaning of incoming information is seen through the lens of a shifting reality. While there is a right answer now, it may be wrong tomorrow due to alteration in the information climate affecting decision.
- Siemens asserted that 'the pipe is more important than the content within the pipe'. This implies that the ability of humans to learn what is needed for today is more important than what is known and imbibing learners with lifelong skills is more crucial than equipping them with knowledge. (p.6).

Ally (2002) asserted that connectivism is a more appropriate learning theory for digital age than older technology theories such as behaviourism and cognitivism. Ally (2002) maintained this position on the idea that the world has changed and become more networked, so learning theories developed prior these global changes are less relevant.

The connectivism theory is applicable to this study because learning could reside in non-human appliances- the computer, the developed IT-integrated packages, CDs DVDs and other software. The Chemistry students' ability to learn what they need for tomorrow is more important than what is known. Students were provided with the IT-integrated packages and other technology tools to help them acquire the needed information about the difficult topics in Chemistry. The students learnt, practised as well as reflected on what they have learnt. Here, the students acquired knowledge and experiences from non-human appliances-computer, animations, simulations and graphics which would help them to imbibe ICT as part of their life in the technology driven era. They could easily use their acquired knowledge in learning other subjects which might improve their performance as well.

1.9 Operational Definition of Terms

- **IT-Integrated Teaching Strategies Packages:** These are the packages developed with integration of Technology into Guided discovery and Teacher demonstration teaching strategies on four difficult topics in Chemistry- mole concept, rates of chemical reactions, electrolysis and redox reactions. They are presented in the form of CD-ROMs. There are two : Information Technology-integrated Teacher Demonstration (ITD) and Information Technology-integrated Guided Discovery (IGD).
- **Guided Discovery Approach:** is an inquiry approach which is a student-centered, activity- oriented teaching strategy in which the teacher guides the students step by step through the use of process skills for students to construct meaningful learning.
- **Teacher Demonstration Method:** is activity-oriented and teacher-centered approach to teaching. The teacher carries out investigation, explains the underlying principles on the investigation and uses the principles step by step to solve problems for students without the assistance or participation of students.
- **Learning Outcomes:** these are the achievements of students in conceptual understanding, problem solving skills, science process skills and 21st century skills in Chemistry after the teaching and learning processes. They are dependent variables in this study.
- **Conceptual understanding:** is the student's ability to demonstrate acquisition of scientific ideas, facts, principles and the careful application of concept definitions, relations, or representations which exist at three levels of thought: macroscopic, microscopic and symbolic. Simply defined in this study as representational competencies and their applications in exploring new situations
- **Problem solving Skills:** the ability to recall and apply certain knowledge and principles for solving a given problem.

- **School Type:** this is the characteristic of the school based on the ownership and funding. On this basis, government owned and funded schools (Public Schools) and private owned and funded schools (Private Schools) are identified.
- **Science Process Skills:** the process of using the senses and appropriate tools to gather information about a phenomenon and drawing conclusions based on reasoning and previous experience. Five basic science process skills considered in the study are: observing, measuring, interpreting, inferring and predicting.
- **21st Century Skills:** certain core competencies required by the students to succeed in the 21st century society and work places. The relevant skills for this study are: critical thinking, communication, collaboration, ICT literacy and leadership skills.

CHAPTER TWO

LITERATURE REVIEW

This chapter provides a review of literatures relevant to the study. It also provides empirical support for the theoretical framework as well as shedding more light into the background and the major concepts involved in the study. The review focussed on major sub-headings.

2.1 Constructivism

This has many variants due to the fact that it is a way of conceptualising knowledge and the process of acquisition of knowledge. It is an approach in philosophy, education and science which argues that knowledge as a justified belief undergoes construction and re-construction by an individual from experiences, observations and interactions in a social setting until understanding and meaningful learning is facilitated. Some classifications of variance of constructivism are rooted and well conceived in the literature and they include: radical, social, cognitive, communal, pragmatic, critical and human constructivism (Hmelo-Silver, Duncan and Chinn, 2007; Kincheloc, 2005; 2008; Novak, 1993 Piaget, 1967; Slezak, 2000 and Von Glasserfield, 2001).

What are some guiding principles of constructivists thinking that must be kept in mind when considering certain roles as educators? Hein (1991) outlines few ideas, all predicated on the belief that learning consists of individuals' constructed meanings and then indicate how each idea influence learning and education:-

- Learning is an active process

In this process, the learner uses sensory input and constructs meaning out of it. The more traditional formulation of this idea involves the terminology of the active learner (Dewey's term) stressing that the learner needs to do something; that learning is not passive acceptance of knowledge which exists ''out there'' but that learning involves the learners engaging with the world.

- Learning is contextual

Humans do not learn isolated facts and theories in some abstract ethereal land of the mind separate from the rest of our lives. We learn in relationship to what we know, what we believe, our prejudices and our fears. On reflection, it becomes clear that this point is actually a corollary of the idea that learning is active and social. We cannot divorce our learning from our lives.

- Motivation is a key component in learning

Not only is it the case that motivation helps learning, it is essential for learning. This idea of motivation as described here is broadly conceived to include an understanding of ways in which the knowledge can be used. Unless we know 'the reasons why', we may not be very involved in using the knowledge that may be instilled in us even by the most severe and direct teaching. This is true that experiential learning facilitates the effective acquisition of knowledge; however, keeping in view the unique characteristics of human brain, it cannot be safely said that each learner passing through a similar experience will learn at the same level and speed.

2.1.1 A Constructivism View of Using Technology in the Classroom

Constructivism emphasizes on the acquisition of knowledge and that knowledge is not accumulated or received, but rather acquired through the active process of learning between learners and their physical social surroundings. This knowledge is further shaped by learners' ability to constantly form different mental concepts and pictures of their newly acquired knowledge (Ma, 2007). Thus, the more the students participate in the lesson, the better they will perform. They benefit from learning by doing and learn through increased interaction and independent time for learning.

In the constructivist environment, the student is in the centre of the learning process, the one who constructs knowledge and meaning, linking incoming or new knowledge and information to existing knowledge. The teacher provides or facilitates the environment for relevant learning by creating whole, authentic, inherently interesting activities and by setting up multiple representations of reality and actual experience for students, thus enabling them to construct their own knowledge. Typical activities for such an environment are investigation, discussion, dramatizing, exploration and negotiation.

The use of technologies could facilitate the implementation of a constructivist approach (Kim, 2008) and assist individual learners in constructing their knowledge and expanding their perspectives. The IGD and ITD met the needs, methodologies and materials that rely on the use of interactive multimedia to integrate cognitive and skills variables (conceptual understanding, problem solving skills, science process skills and 21st century skills), and to achieve lesson objectives; provide authentic learning experiences; offer learners control over their learning and also focus on the content (Tsai, 2010).

2.2 Nature of Chemistry

Chemistry is one of the most important branches of science dealing with the composition, structures and properties of matter, the interactions between different types of matter and the relationship between matter and energy. Through the learning of chemistry, relevant conceptual and procedural knowledge are acquired. A study of Chemistry is needed to develop understanding and appreciation of developments in engineering, medicine and other related scientific and technological fields. Such relevant knowledge would assist students to develop an understanding of the relationship between science, technology, society and the environment (Education and Manpower Bureau, 2005).

However, students have been found to encounter difficulties learning the subject at all levels of education. These difficulties may be due to the abstract nature of the subject (Kousathana & Tsaparlis, 2002; Raviolo & Garritz, 2008; WAEC 2005, 2007, 2011; Acar & Tarhan, 2007;

Opara, 2009; Berg, 2012). They may also be due to conceptual and procedural difficulties associated with the learning of the subject (BouJaoude & Barakat, 2000; Chandrasegaran, Treagust, Waldrip & Chandrasegaran, 2009).

One of the essential characteristics of chemistry learning is the constant interplay among the macroscopic level of thought at the tangible and visible, the microscopic at the molecular, atomic and kinetics levels and the symbolic representation of the equations, stoichiometry and mathematics level (Johnstone, 1993). It is at the symbolic level of chemistry (and physics) learning that a significant challenge occurs as chemistry curricula commonly include many abstract concepts which are essential for advanced learning in both chemistry and other sciences (Taber, 2002). It has been shown that the skills in translating among the representations are often limited among chemistry students because their understanding is confined to the surface features of a representation at the macroscopic level such as colour, density appearance and all physical properties (Bowen & Bunce, 1997; Kozina & Russel, 1997; Treagust, Chittleborough & Mamiala, 2003). That is, students have difficulties in understanding concepts at the microscopic and symbolic levels and in integrating mentally across the three levels.

However, the most prevalent studies on students' understanding in chemistry are on the identification of their misconceptions and correct conceptions on certain chemistry topics. There exist few studies on students understanding at the three levels of thought (macroscopic, microscopic and symbolic) either in relation to the students' levels of thought (Sanger & Phelps, 2007), ability to solve quantitative problems (Kelly & Jones, 2008) and acquisition of skills or attitude to chemistry learning (Gilbert & Treagust, 2009; Omilani, 2010).

Many studies have also found that the interplay between macroscopic and microscopic worlds is a source of difficulty for many chemistry learners (Sirhan, 2007). This has been shown in the teaching of the Mole Concept (Adesoji, 2004; Ellis, 2009), Organic Chemistry (Szu, Nandagopal, Shavelson, Lopez, Penn, Scharbergs, & Hill, 2011; Flynn 2011; Agogo & Onda, 2014), chemical bonding (Dhindsa & Treagust, 2009; Kind & Kind, 2011), kinetic theory (Agogo & Onda, 2014) and ionic bonding (Taber & Coll, 2003; Coll & Treagust, 2003).

Three levels of understanding of concepts identified in education particularly in Chemistry by Anderson (1990) and Johnstone (1991) are the macroscopic, microscopic and symbolic levels. The macroscopic level is a concrete level of understanding which corresponds to knowledge acquired through observing objects such as physical properties of an object and change in states of matter. The microscopic level is an abstract level, which corresponds to observable phenomena at the macroscopic level. For learning to be effective, the concepts ought to be understood meaningfully at all levels. Johnstone (1993) placed these three levels at the vertices of a triangle and emphasized that "every student studying chemistry for whatsoever purpose needs to operate within the triangle" as shown in figure 1.1.

In general, the difficulties that students at all levels of education encounter in understanding chemical concepts can be summarized as follows: inadequate conceptual knowledge, inability to interrelate the content representation at macroscopic, microscopic and symbolic levels and the unobservable particulate and mathematical nature of much of chemistry content (Gabel, 1999; Kelly, Phelps & Sanger, 2004; Stain & Talanquer, 2008; Tsoi, Goh & Chia, 2010).

2.3 Performances in Chemistry

Performance of students in chemistry examinations or achievement test shows whether effective learning has taken place and/or the understanding of the subject or some certain concepts in the subject. In Nigeria, there has been consistent poor performance of students in public examinations conducted by the West African Examinations Council (WAEC) and the

National Examination Council (NECO) in the sciences across the country over the years (Agogo, 2003; Samba & Eriba, 2012). Table 2.1 shows the poor performance of students in the basic science subjects in the WAEC examinations over the years.

Table 2.1: STUDENTS' PERFORMANCE IN SENIOR SECONDARY SCHOOL CERTIFICATE EXAMINATIONS (SSCE) INTHE MAJOR SCIENCE SUBJECTS (WAEC MAY/ JUNE 2006-2014)

	CHEMISTRY		BIOLOGY		PHYSICS		AGRIC SCIENCE	
YEAR	NO OF CANDIDATES WHO SAT FOR THE EXAMINATI ON	% OF CANDI DATES WHO PASSED WITH CREDIT GRADE(1-6)	NO. OF CANDIDA TES WHO SAT FOR THE EXAMINN ATION	% OF CANDIDA TES WHO PASSED WITH CREDIT GRADE(1-6)	NO. OF CANDIDAT ES WHO SAT FOR THE EXAMINAT ION	% OF CANDIDA TES WHO PASSED WITH CREDIT GRADE(1-6)	NO. OF CANDIDAT ES WHO SAT FOR THE EXAMINAT ION	% OF CANDIDATES WHO PASSED WITH CREDIT GRADE(1-6)
2006	380,104	44.90	*1,137,131	49.23	375,824	58.05	907,232	35.01
2007	185,949	44.44	427,644	33.94	200,345	48.26	436,751	44.32
2008	215,113	48.26	985,740	44.31	418,423	44.44	*1,259,983	33.94
2009	468,643	43.69	*1,340,206	28.59	465,636	47.83	*1,059,983	46.41
2010	465,643	50.70	*1,300,418	49.65	463,755	51.27	*1,024,039	47.25
2011	565,692	49.54	*1,505,199	38.50	563,161	63.94	*1,190,796	52.60
2012	627,302	43.13	*1,646,150	35,66	624,658	68.74	*1,318,597	52.40
2013	639,913	72.05	1,646,741	51.66	636,857	46.62	1,347,344	73.10
2014	644,913	61.88	1,377,161	55.47	644,391	60.21	952,642	61.60

Source: The West African Examination Council (WAEC), National office, Ikeja, Lagos, Nigeria (Test Development Division Centre)

Key = *High enrolment

The WAEC Chief examiner's report particularly confirmed this poor students' performance in chemistry (Chief Examiner's Reports, WAEC, 2011 - 2014).

Many reasons have been adduced for this poor performance in chemistry. According to Samba and Eriba (2012), it may be due to the abstract nature of chemistry concepts while Mailumo, Agogo and Kpagh (2007) hinged it on student and teacher related factors. Part of the teacher related factors is the teaching methods employed by teachers to teach the concepts.

Teaching methods employed by the chemistry teachers have been shown to have significant effect on chemistry students' performance. For example, the effect of games method of teaching on students' academic achievement in chemistry was studied by Longjohn (2009) using pre-test post-test quasi experimental research design, the result showed that the group of students taught by games method performed significantly better than the control group. The implication is that chemistry teachers are encouraged to use innovative method of teaching that involves students' participation.

Osokoya & Opateye (2009) investigated the effect of action-based testing mode (an experiment that aims at exhibiting a particular scientific concept and ability to carry out activities and answer questions on the actions performed within the limit of time given) and test anxiety on secondary school students' performance in electrochemistry. The findings showed that students exposed to action-based testing performed better than those of conventional testing and that there is significant main effect of treatment (action-based testing mode) on students' achievement in electrochemistry. It was therefore recommended that chemistry teachers adopt action-based test to aid students in the effective learning and understanding of electrochemistry concepts. Similarly, Akinsola & Igwe (2002) determined the relative effect of framing strategy on students' achievement in selected difficult chemistry concepts using the pre-test, post-test quasi experimental research design. The result showed that students exposed to framing teaching strategy performed better than those taught with the conventional method of teaching.

On the other hand, prior knowledge to have a correlation effect on students' performance in chemistry. Michael (2009) examined the role of prior knowledge in first year performance of undergraduate chemistry. The result showed that there were significant differences between the mean scores of students who have and those who do not have prior knowledge of chemistry in semester tests and end of year 1 examinations with the former group obtaining higher scores. Correlation analysis shows a strong correlation between prior knowledge and examination performance.

In like manner, Szu, Kiruthioga, Richard, Enrique, John, Maureen & Geannine (2011) examined the factors related to students' performance in organic chemistry courses. Results indicated that high-achieving students as measured by course grades, score higher on measures of conceptual performance and problem-solving while seeking assistance and engaging in practice problems earlier in the semester than low-achieving students. Also, Bell & Volckman (2011) used knowledge surveys (confidence, over-confidence and performance) to assess changes in students' understanding of their own learning in General chemistry. The study compared metacognitive confidence ratings of students faced with problems on the surveys with their actual knowledge as shown in the final examination in two courses of General chemistry. The surveys were administered at the start and the end of the course and correlated with final examination scores. The result showed that students scoring high in the examinations estimated their knowledge with greater accuracy than the lower-scoring students who overestimated their knowledge. Some other researchers suggest that the poor performance may be due to the difficulty of chemistry concepts (Agogo, 2003 and Agwi, 2008).

Therefore, it can be concluded that there are many factors that can affect the performance/achievement of students in chemistry. The factors include teacher and student factors such as type of testing, metacognitive confidence ratings, engagement in practising problem solving, prior knowledge. Other factors are teaching strategies and difficulty of chemistry concepts. All these have been identified as factors that influence performance/ achievement of students in chemistry.

2.4 Factors Influencing Students' Learning Outcomes

There are many factors that influence students' learning outcomes and achievement in Chemistry. Relevant to this study among the numerous are: teaching strategies, students' conceptual understanding, problem-solving skills, students' gender, school type and many others.

2.4.1 Teaching Strategies and Students' Learning Outcomes

Achievement in the teaching and learning process has to do with attainment of set objectives of instruction (Nbina & Obomanu, 2011). Studies have shown that the teaching of science in Nigerian secondary schools falls short of the standard expected of it. Most of the methods used in teaching have been described as inappropriate and uninspiring (Ibe, 2004; Madu, 2004; Shaleigh, 2004). Nnaobi (2007) asserts that there is no best method of teaching but that effective scientific teaching should be laboratory-centred and activity-oriented rather than textbook or lecture-dominated methods which seem to characterize the Nigerian schools.

2.4.1.1 Guided Discovery Approach and Students' Learning Outcomes

The guided-discovery method is a student-centered, activity- oriented teaching strategy in which the teacher guides the students through problem solving approach to discover answers to instructional topics at hand (Abdullahi, 2007). It is the recommended method for science teaching in Nigeria. According to Akinsete (2006), it is a method of teaching that encourages a child to solve problems by seeking and asking questions so as to gather information. Guided discovery involves discovery in which there is creativity and students participation in a well equipped learning environment. Akinsete (2006) also notes that this method of teaching aids conceptualization, memory and helps to develop students understanding of science. Adeoye

& Raimi (2006) in the same vein summarized that this method makes activities enjoyable, accessible and promote students language and communication skills. Oloyede (2010) compared the relative effectiveness of guided discovery and concept mapping teaching strategies in relation to the students' performance in Chemistry while Nbina (2013) assessed the relative effectiveness of guided discovery and demonstration teaching methods on achievement of chemistry students of different levels of scientific literacy. The result indicated that the guided discovery method is superior to the demonstration method in promoting cognitive achievement in chemistry amongst students of all levels of scientific literacy.

Mfon (2011) investigated the relative effectiveness of problem-solving, guided discovery, and expository methods of instruction on students' performance in redox reaction, considering their mathematics ability. It was a quasi experimental research using non-randomized-pre-test–post-test control group design with expository method as control. The results showed that those taught using problem-solving method performed significantly better than those taught with guided-discovery and expository methods; expository approach was the least facilitative. Students' performance was observed not to be dependent on their mathematics ability.

2.4.1.2 Demonstration Teaching Strategy and Students' Learning Outcomes

Demonstration method is a teaching strategy which involves experimentation. Demonstration can be carried out by the teacher for the students to observe and/or the teacher and other students to observe (Nwachukwu & Nwosu, 2007; Nbina, 2013). The method being activity-oriented is executed by example to enhance cognitive, affective and psychomotor domains of instructional objectives. Demonstration also appeals to the student sense of sight and hearing and could be presented to the entire class, small group of students or to an individual student. According to Nwachukwu & Nwosu (2007), the teacher can promote maximally the gains of demonstration method through conscious manipulation of elements of classroom interaction. These elements/techniques of classroom interaction include stating instructional objectives, planned repetition, active students' involvement, reinforcement and questioning. It is the effectiveness of manipulation of classroom interactions that help the students to achieve more of cognitive objectives. They argued that the demonstration method can promote cognitive achievement as it can be applied at different levels of instructional objectives if well planned by the teacher.

2.4.2 Conceptual Understanding in Chemistry

Conceptual understanding simply means understanding of certain concepts that is, the ability to construct one's own meaning or knowledge about a concept. There are a lot of studies in this area. Researchers studied how different concepts can be better understood. Frailich, Miri & Avi (2008) worked on enhancing students' understanding of the concept of chemical bonding by using activities provided on an interactive website. Two groups participated in the study – an experimental group and a control group. The participants in the experimental group were taught with four activities taken from a website all dealing with the concept of chemical bonding. Computer based visual models were used in all the activities to demonstrate bonding and the structure of matter: all are based on student-centered learning.

The participants in the control group were taught with traditional method of teaching. The result showed that the experimental group outperformed the control group significantly in the achievement post-test which examined students' understanding of the concept of chemical bonding. The implication of the result is that web-based learning activities provided students with opportunities to construct their knowledge regarding the concept of chemical bonding and so, it will help students' conceptual understanding of other concepts.

Also, Stefani & Tsaparlis (2009) investigated students' knowledge construction of basic quantum chemistry concepts namely atomic orbital, Schrodinger equation, molecular orbitals, hybridization and chemical bonding. The result showed the main problems as insistence on the deterministic models of the quantum, the misinterpretation of models and the poor understanding of the current quantum concepts. Combining levels of explanations with levels of models, four categories were derived – two are shades of variable in the rote-learning part of a continuum while the other two categories are in the meaningful learning part.

Costus, Alipasa & Mansoor (2009) worked on how to promote conceptual change in the first year students' understanding of evaporation. They took the position that teaching strategy (Predict-Discuss-Explain-Observe-Discuss-Explain –PDEODE) helped students to achieve a better conceptual understanding and that teaching strategy enabled students to retain their new conception in their long-term memory.

Marchlewicz & Wink (2011) used the activity model of inquiry to enhance general chemistry students' understanding of the nature of science. The activity model of inquiry is a theoretically grounded and empirically derived model of scientific inquiry and could be used as a thinking frame to help students develop more informed views of the nature of science. The results from the essay and pre- and post questionnaires showed that students shifted in their views of nature of science.

Brett (2012) realizing that inquiry has been advocated as an effective pedagogical strategy for promoting deep conceptual understanding and more sophisticated scientific thinking by numerous bodies associated with chemistry (and science) education, introduced the notion of framing (a form of scaffolding) by presenting a model designed to help teachers more effectively frame inquiry activities. The model introduces five components of the framing process that can be employed by teachers as guidelines for developing the background information they will share with students prior to an inquiry activity. Those components are context, goals, actions, tools and interactions. The results showed that the students had better orientation to the purpose of inquiry. Also, the model put boundaries on the problem space explored and reduced the cognitive load as they engage in the activity.

Using Art-Based Chemistry Activities (ABCA) to improve students' conceptual understanding in Chemistry was the study of Dennis and Marlene (2011). The study aimed at determining the effects of art-based chemistry activities (ABCA) on high school students' conceptual understanding in chemistry using the pretest–posttest control group design. The result showed that ABCA students showed better understanding of the concepts. The intervention produced positive effect on the concept understanding of students in Chemistry.

David & Provi (2011) assessed the students' conceptual understanding of acids/bases in organic chemistry context. The results indicated that most students maintained declarative knowledge rooted in general chemistry training related to acids/bases, but they cannot apply it in problem solving tasks. This assertion held true for most participants, whether chemistry majors or pre-professional majors. Furthermore, flaws in student conceptual understanding of acid/base chemistry principles were identified.

Opara (2009) studied enhancing understanding of stoichiometry through self-regulation; the design of the study was pre-test, post-test non-equivalent control group design. The result showed that when students build up capacity to regulate their learning, they performed better than those taught by traditional methods.

Cullen & Pentecost (2011) studied enhancing conceptual understanding of electrochemistry using guided inquiry laboratory experiment. They investigated students' conceptions of electrochemical cell and identified their difficulties. Laboratory experiment was then integrated into the teaching to improve conceptual understanding and remove the difficulties.

The use of analogy to enhance conceptual understanding in different topics of chemistry has been the focus of some research studies; 'analogy' has been adopted to represent the visualization of concepts through the analogical comparison between two fields: a known field and the scientific conceptual field. Andre & Andoni (2009) compiled the list of analogies used in teaching chemical equilibrium from some journals and textbooks. Thirty-nine (39) different analogies were found illustrating different aspects of chemical equilibrium viz; Dynamic aspect, equality rates, reversibility, calculation of equilibrium constant, change in the conditions and function of catalyst. They admitted that though analogies may increase conceptual understanding of the concept yet, the improper teaching of an analogy can lead to confusion or to the alternative conceptions. The thirty-nine (39) analogies founded were classified into five categories thus:

1. Familiar analogues,
2. Games,
3. Experiments,
4. Flow or transference of fluids,
5. Machines.

In conclusion, research studies showed that students' conceptual understanding can be promoted or enhanced by using different teaching strategies, laboratory experiments, web-based activities, analogies and many others to help the students construct their own meaningful knowledge and to retain new conceptions in their long-term memory

2.4.3 Studies on Problem-solving Skills in Chemistry

Danjuma (2005) defines problem solving as a process whereby an individual or a group uses previously acquired knowledge and skills to meet (solve) the demand of a particular situation (problem). There is a problem when someone is confronted with a challenge for which an immediate answer is not available. Danjuma (2012) came up with the commonality in ideas about the concept of a "problem". First, for a question, a goal or an objective to be a problem it must be a challenge to the solver. Second, the solver must be willing to accept the challenge.

Third, the solver must have no readily accessible methods for obtaining the solution to the question, goal or objective. These three conditions have to be satisfied for a situation to be regarded as a problem.

One of the important goals of education is the acquisition of problem-solving skills. In chemistry, demonstration of good problem-solving skills would likely lead to good performance in different aspects of chemistry. Assessing problem solving skills and its various ways of utilization enables students to learn faster and perform within the conceptual process.

Students' ability to develop problem-solving skills depends largely on a teacher's instructions. Conventional teaching methods which rely predominantly on presenting information, showing prototypical examples of workout problems and providing students with practice in solving similar kind of problems do not help to develop the students' problem-solving skills.

Research studies on problem solving in chemistry find that many students do not understand the chemistry concepts involved in chemistry problems or are unable to apply the conceptual knowledge in solving the problems. They mainly use algorithms or principles to arrive at correct answers.

What strategies do high school students use when solving chemistry problems? What are the variables to look for when solving an open-ended problem is referred to as problem solving skills. The literature on problem solving skills is characterized by displaying multiple theoretical frameworks from cognitive science or information processing. Sugrue (1995) examined common issues of some of these models, in order to identify a set of cognitive components that could be measured to estimate the extent to which a student can solve problems within a domain, such as science, as well as provide a basis for selecting a subset of variables to be submitted for evaluation.

The three cognitive components to be assessed in problem solving following Sugrue model are:

• Cognitive Functions, component that supports flexible adaptation of self-knowledge to meet the demands of a new problem. It is related to the so-called meta-cognitive functions, or processes of higher order thinking,

• Beliefs, component that aims to generate a comprehensive profile of the student's ability and willingness to solve problems in a particular domain, through variables: self-efficacy, perception of task demands and perceived attractiveness of the task,

• Knowledge structure, this component consists of three levels that, in a perfect performance, show a high degree of connectivity, integration and consistency.

Sugrue (1995) suggests that the ability to solve problems in a particular domain results from the complex interaction of the structure of knowledge, meta-cognitive functions and motivation. The differences observed during the process, from the interpretation of the problem to the persistence in trying to solve it, can be attributed to variations in these three aspects of cognitive constructs. For each of the three categories of cognitive components, Sugrue (1995) describes a limited set of variables that should be targeted by assessment under two criteria: they were shown to be critical by research or open to instructional intervention. Developing tools to assess achievements in the component knowledge structure is the focus of this study. Therefore, the theme is developed in more detail;

Knowledge structure assessment

This component of Sugrue model considers three levels:

• First level: Concepts. A concept is a category of objects, events, people, symbols and ideas that share common attributes and properties, and are identified by the same name. The evaluation of the understanding of a concept implies: selecting examples of the concept (in a multiple choice format), or generating of examples of the concept (in an open-ended format), or explanation of why examples reflect concept attributes (in a hands-on format).

• Second level: Principles. A principle is defined as a rule, law, formula or statement that characterizes the relationship (often causal) between two or more concepts. The evaluation of the understanding of principles involves: selecting best predictions or best explanation (in a multiple choice format), or generating predictions or solutions (in an open-ended format), or giving an explanation of an event or result (in a hands-on format).

• Third level: Linking the concepts and principles to conditions and procedures for application. To facilitate the resolution of the problem, the concepts and principles should be linked to the conditions and procedures that facilitate their use in new situations. A procedure is a set of steps that can be done to achieve a goal. The conditions are aspects of the context that indicate the existence of an instance of a concept, or to indicate that a principle is operating or can be applied, or that a particular procedure is appropriate. Subjects with good performance in problem solving should be able to recognize situations where procedures can be performed to identify or generate instances of a concept and should be able to carry out these procedures exactly. Overall, they should be able to assemble a procedure based on a principle to construct a desired achievement in a new situation.

The evaluation of this level involves: selecting correct procedure for identifying instances of a concept, or selecting most appropriate procedure to change the state of one concept by manipulating other (in a multiple choice format); or generating a procedure for identifying instances of a concept, or generating a procedure to change the state of one concept by manipulating other (in a multiple-choice format); or performing procedures to identify instances of a concept, or performing a procedure to change the state of one concept by manipulating other (in a hands-on format).

The diagnostic evaluation of problem solving skills should allow the identification of students who understand the concepts but not the principle that binds them, students who understand the principles and concepts but have no knowledge of the procedures for applying them, and students who are able to perform procedures correctly but do not know when it is appropriate in their application.

Morales (2014) developed and validated tests to assess the achievement in problem-solving skills in general chemistry course following the model proposed by Sugrue (1995) to measure problem-solving skills. The tests were constructed for a General Chemistry course in a curriculum of engineering, which implements PBL methodology at a Peruvian university. Then the items were written taken as reference Sugrue model for evaluating three levels of Knowledge Structure: concepts, principles and link the concepts and principles to conditions and procedures for application, resulting in the construction of three tests, one for each topic: Thermodynamics, Kinetic and Chemical Equilibrium. The results obtained showed difficulty degree and items response pattern. Morales concluded that the three levels of Sugrue (1995) model are appropriate tools for assessing these skills.

Lee (1985) did a study in Australia to investigate cognitive variables that affect problem-solving performance in electrochemistry. Two hundred and fourteen Grade 12 chemistry students from six high schools were involved in the study. The study has shown that successful problem solving is related to several important cognitive variables which can be grouped as block variables, namely linkage skills (concept relatedness and idea association), problem recognition skills (problem translating skill and prior problem solving experience) and prior knowledge (specific knowledge and non-specific but relevant knowledge). These block variables consist of predictor variables as shown in the above brackets. In addition, the influence of these predictor variables on the success of problem solving varies with the familiarity of the problems.

Chandrasegaran, Treagust, Waldrip & Antonia (2009) identified students' dilemmas in reaction stoichiometry problem solving; deducing the limiting reagent in chemical reactions. They studied students' written problem-solving strategies using the think-aloud protocol during problem solving and retrospective verbalizations after each activity. The results showed that the high achieving students tend to rely on the use of memorized formula to deduce the limiting reagent, by comparing the actual mole ratio (AMR) of the reactants with the stoichiometric mole ratio (SMR). The average-achieving students, however generally deduced the limiting reagent from first principles, using the stoichiometry of the balanced chemical equation. It was discovered that only high achieving students were able to deduce the limiting reagent with some degree of confidence (but not always) during problem-solving and to perform related computation.

Overton & Potter (2011) were concerned with how students solve open-ended, ill-defined problems in chemistry. In their study, three (3) cognitive variables of working memory, metacognitive-capacity and field dependence-independence were measured. The result showed that there was a significant difference between the cognitive variables required for success in traditional algorithmic problems and open-ended problems. The context-rich open-ended problem significantly shifted students' attitude towards problem solving.

Taasoobshirazi & Glynn (2009), showed how a theoretical model of expertise contribute to the successful solution of quantitative, well-defined chemistry problems in the areas of stoichiometry, thermochemistry, and properties of solutions. The result indicated that the students' problem conceptualization and chemistry self-efficacy influenced their strategy use, which, in turn, strongly influenced their problem-solving success.

Success of non-mathematical problem solving in organic chemistry was investigated upon by David & George (2009). The participants in this study who were "more successful" adopted consistent approaches to solving the problems. They were more likely to draw molecular fragments obtained during intermediate stages in the problem-solving process; were better at mining the spectral data; and were more likely to check their final answer against the spectra upon which the answer was based.

2.4.4 Students' Gender and Learning Outcomes

Gender is the property that distinguishes organisms on the basis of their reproductive roles as female or male (Abubakar & Uboh, 2010). Gender is a cultural construct that distinguishes the roles, behaviour, merits and emotional characteristics between female and male developed by the society. The concept of gender does not support or suggest the dominance of male over female or vice versa in academic and other human resource development areas but it stresses equality and equity in enhancing effective and efficient recognitions, development, utilisation of competences and endowed capacities of both sexes.

Adesoji & Babatunde (2008) reported that more female than male students had difficulties and held misconceptions in inorganic Chemistry in the senior secondary school. Many studies also show that male students consistently achieve higher than their female counterparts in science (Okonkwo & Eke, 2005; Eriba & Ande, 2006; Njoku, 2007; Okigbo & Akusoba, 2009). However, Iorchugh (2006) and Udo (2006) showed no significant effect of gender on students' achievement in science. Gender differences may have influenced the gap in the performance of boys and girls in Chemistry in particular and science as a whole at the senior secondary school level (Onekutu, 2002). It seems that female students now tend to avoid Chemistry and this may be responsible for the gap between female and male that offer Chemistry at the secondary schools. Several research reports (Esiobu, 2005; Okoli, 2009; Udeani, 2009; Udeani & Ejikeme, 2011) showed that gender gaps exist in science and technology education and employment opportunities in Nigeria. Udeani & Ejikeme (2011) reported that females were under-represented: they occupy the middle and lower status in science and technology. Okebukola (2004) reported that in spite of the fact that 50% of the population of Nigeria is women only, 11% of personnel in science, technology and engineering professions are women. What is responsible for this gender gap in science especially in Chemistry? There are biases and misconceptions about women and science that see science as a male enterprise (Erinosho, 2006). Many researchers have provided reports that there are no longer distinguishing differences in the cognitive, affective and psychomotor skill achievements of students by gender (Arigbabu & Miji, 2004; Bilesanmi-Awoderu, 2008; Olatoye & Adekoya, 2009; 2010). That is, there is no significant difference in the learning outcomes of male and female students. Furthermore, Ehindero (2006) investigated correlation of sex-related differences in logical reasoning and showed that males scored higher than females on male-related tasks and female higher on female-related tasks. No significant difference was observed on the related content-free tasks.

Yusuf & Adigun (2010), Udosoro (2011), Achori, Kurumen & Orokpo (2012) and Muhammad (2014) found that gender is a predictor of students' achievement in Chemistry but found no significant difference in the achievement of male and female students in the subject. Omoteso & Sadiku (2013) also found no significant difference in the performance of Nigerian male and female students in Chemistry using Preview, Question, Read, Reflect, Recite and Review (PQRRRR) study techniques. Sheu (2015) concluded that there is no significant difference in achievement of male and female students taught using Problem Solving and Lecture teaching methods in Mole Concept. Amogne (2015) analysed gender disparity in the Ethopian regional examination and found no significant difference between male and female students both in average results and subject wise. Menon (2015) also showed no significant difference in the academic achievement of male and female in India secondary school students in Chemistry when taught through multimedia approach and conventional teaching method. Lamidi, Oyelekan & Olorundare (2015) showed no significant difference between male and female Nigerian senior secondary school students on Chemistry achievement in mole concepts when taught using mastery learning teaching method.

However, Lawal (2009), Igboegwu & Okonkwo (2012) showed a significant difference in the achievement of Nigerian male and female secondary school students in Chemistry in favour of female. Eniayeju (2010) showed that male students significantly achieved higher than their female counterparts in science. In addition, Adesoji (2007) found no significant interaction effect of teaching strategies (Cooperative, Individualized and Competitive) and gender on students' academic achievement. Also, Olatoye, Aderogba & Aanu (2011) showed no significant interaction effect of teaching strategies (Cooperative and Individualised) and gender on students' achievement in Chemistry.

The studies reviewed so far on gender difference in Chemistry achievement do not agree. Some studies showed significant difference in students' achievement in favour of males, other studies showed significant difference in favour of female students while some other studies showed no significant difference of gender in Chemistry achievement.

2.4.5 School Type, Facilities and Students' Learning Outcomes

Education being a social necessity is regarded by some scholars to be a public good while some believe that what is being invested in education should be reaped by the investor. In this sense, the investor could be an individual of the society. The establishment of many private schools has contributed in no small way in satisfying people's wants as to which schools their children and wards would attend, but at the same time, the inherent costs of private schools and the Lagos State Government position of free secondary education places the low income earners who desire the best in terms of quality education for their children but cannot at times pay the exorbitant fees of the private schools when they are in a difficult financial situation. The inputs variables such as infrastructural facilities provided by the secondary school for teaching and learning process, irrespective of the ownership of the schools remain indispensable variables used to produce quality output (Abari & Odunayo, 2012).

Schools, irrespective of ownership are expected to function in compliance with the achievement of the national education objectives. The effectiveness of a school system is determined by the performance of its students in external examination. The better the performance of the students, the more effective the system is assumed to be (Philias & Wanjobi, 2011). Cynthia & Megan (2008) in United State of America confirmed a strong and positive relationship between quality of school facilities and students' achievement in English and Mathematics. However, Bowers & Urick (2011) investigated the effects of high school facility quality on student achievement using a large, nationally representative U.S. database of student achievement and school facility quality. They found no evidence of direct effect of facility on student mathematics achievement. Nasser (2008) studied the level of ICTs in Lebanese public and private schools for the academic year 2005/2006 and evaluates the effectiveness of ICT on student school performance. The results showed that students in public schools outperformed students in private schools in the baccalaureate examinations.

In Nigeria, it is the general opinion of people that private schools are better in terms of the availability of human and physical facilities and consequently, students' performance is expected to be better than in public schools. The studies of Cythia & Megan (2008), Philias & Wanjobi (2011), Vandivercl (2011) and Alimi, Ehinola & Alabi (2012) showed strong positive relationships between qualities of school facilities and achievement. The finding of Robert (2009) and Alewu, Nosiri & Ladan (2011) on types of schools and students' achievement in Nigeria revealed that students in private schools performed relatively better that their counterparts in the public schools in mathematics and science subjects. However, Philias & Wanjobi (2011) and Alimi, Ehinola & Alabi (2012) found no significant difference in academic performance of students in the two types of secondary schools but significant difference existed in facilities available in public and private schools in favour of private schools. This is to show that whether a student attends a private or a public school does not really matter but what have been found to be related to students' performance are the facilities available in the course of programme implementation. It could also be that most of the private secondary schools use comparable salary structure with public schools. Some private schools have been found to be paying even higher salaries than public schools. All these factors may be the reasons why private schools are often expected to perform better. However, while some research findings showed that private school students performed better in academic achievement than their public school counterparts, Okon & Archibong (2015) and Abari & Odunayo (2012) found no significant difference in the academic performance of students in the SSCE between the public and private senior secondary schools.

In agreement with Marc & Ping (2015), the differences in learning outcomes of students who attend private and public schools lie more on the school resources and practices and less on student characteristics.

2.5 Skill acquisition

Skills are so important for students to acquire while in school to be adequately prepared for the outside world when they join the workforce. There are different kinds of skills to be acquired by Chemistry students viz problem solving skills, metacognitive skills, science process skills, 21^{st} century skills and so on in chemistry learning. Some employers find chemistry graduates lacking in written and oral-communication skills, critical thinking skills, group-work skills, as well as the ability to efficiently analyze data and retrieve chemical information.

2.5.1 Science Process Skills

Science process skills are the skills utilized by teachers in the delivery of teaching the facts of science effectively. This is because science is not just of knowledge but it is a way to systematically understand the environment. Science process skills are required by students to learn about the world of science and technology in more detail. Students are able to learn science in a meaningful way through an exploration of science process skills based on the constructivist approach (Yeam, 2007). Science process skills are behaviours that promote the formation of skills applied to acquire knowledge and then disseminate what is obtained thus increasing the use of optimum mental and psychomotor skills.

Science process skills in science are very important to develop scientific ideas and to make learners independent thinkers. Process skill is a preparation to becoming a Scientist (Yadav & Mishra, 2013). The underlying skills which govern the scientific method which is organised and systematic in exploring or investigating nature in a testable and verifiable manner in order to establish presumed relations among phenomena with the basic aim of improving our understanding of nature are referred to as science process skills. These skills are used in the experiments by the scientists and science students as well as in the everyday life of average person, to a degree. Process skills are the sequence or events that are engaged by the researcher while taking part in scientific investigations. Process skill as a series of connected actions, experiences or changes which go on internally within a learner and can usually be demonstrated externally. Process skills are important to formal presentation of science.

The term science process skills are popularised by the curriculum project, Science- A Process Approach (SAPA). It is componential of a set of broadly transferable abilities appropriate to many science disciplines and reflective of the behaviour of scientists which are grouped into two types and these are: basic and integrated (Padilla, 1990). The basic science process skills consist of six types of skills and these are:

- Observing
- Inferring
- Measuring
- Communicating
- Classifying and
- Predicting.

  The integrated science process skills consist of another six types of skills and these are:

- controlling variables,
- Defining operationally,
- formulating hypotheses
- interpreting data
- Experimenting and
- Formulating models.

Acquisition of basic science process skills is the prerequisite to the acquisition of higher order skills needed in technology and manufacturing. Hence, the emphasis on basic science process skills.

Teaching methods employed in teaching science have significant effect on students' learning outcomes particularly on acquisition of science skills. The findings of Bilgin (2006) showed that when hands-on learning activities were used together with Cooperative learning approach, the sampled students were more successful in the development of science process skills and had more positive attitude towards science than the control group students taught in the traditional methods. The review carried out by Hofstein & Naaman (2007) on several studies conducted in various countries including Nigeria about laboratories applications showed that laboratory activities enhanced students' comprehension of Chemistry concepts, students' science process skills, problem-solving skills and their interest and attitudes towards scientific approaches in accordance with the objectives of basic science education. The study of Nbina (2013) on relative effectiveness of guided discovery and demonstration teaching methods on students' cognitive achievement at different levels of scientific literacy and acquisition of science process skills found guided discovery significantly superior to demonstration method. Nworgu & Otum (2013) examined the effect of guided inquiry with analogy instructional strategy on students' acquisition of science process skills. The study showed significant positive effect of guided inquiry with analogy instructional strategy on students' acquisition of science process skills as against traditional lecture method.

The study of Yager & Akcay (2010) also determined the effect of inquiry approach to science instruction in middle grades in Iowa. The study indicated that students who were taught with inquiry method, used and understood science concepts and skills significantly than those students in typical traditional classes in terms of process skills, creativity skills, ability to apply science concepts and the development of positive attitudes. The study showed significant higher acquisition of science process skills of Biology students in inquiry method than lecture method.

Gultepe & Kilic (2015) investigated the effect of argumentation on the development of science process skills in the context of teaching Chemistry. The study determined the differences in integrated scientific process skills of Turkish grade 11 Chemistry students who were taught with scientific argumentation and traditional teaching methods. The results showed that the scientific argumentation was more effective in acquiring science process skills than the traditional teaching approach. However, Ayodele, Olatubosun & Daramola (2014) showed that science students' acquisition of science process skills has been hampered by teacher's factor, inadequate resources, too large class size and lack of time allocation in the school time table.

In line with developments in technology and the explosion of knowledge in the digital-age, the 21st century skills can be cultivated through scientific literacy and science process skills especially for science students.

2.5.2 21st Century Skills

There has been a global shift over the last century from manufacturing to emphasizing information and knowledge services. The greater emphasis is now being placed on the acquisition of life coping skills and/or what is generally now referred to as 21st century skills. These include decision –making, information-sharing, collaboration, innovation and speed skills which are essential in today's enterprises. The 21st century skills refer to a broad set of knowledge, skills, work habits and character traits that are believed to be critically important to attain success in today's world of information and technology particularly in collegiate programmes and contemporary careers and workplaces (The Partnership for 21st century skills (P21) learning framework, 2007; Riddle, 2009). Success in today's world requires the ability to access, synthesize and communicate information; to work collaboratively across differences to solve complex problems and to create new knowledge through the innovative use of multiple technologies (Ledward & Hiratta, 2011). Ledward & Hiratta (2011) provided a framework for understanding the relevance of 21st Century Skills and highlights research on their impact on learners. The findings are:

1. The world in which learners find themselves today is fundamentally better than before; the expansion of information and communication technology is transforming the nature of learning.
2. 21st Century Skills establish new learner standards by integrating core-subject mastery and contemporary, interdisciplinary themes (e.g., civic literacy, global awareness and environmental literacy).
3. With the learning environment and teacher competency as primary factors, the development of these skills can be achieved in many ways (e.g., place-based, project-based, or problem-based learning).

4. Although research in this area is relatively young, existing evidence links 21stCentury Skills with positive learner outcomes.

The Partnership for 21st Century Skills (P21) has created a comprehensive framework for conceptualizing different types of skills important for college and the workforce. For example, learning and innovation skills include creativity and innovation, critical thinking and problem-solving, communication and collaboration. Information, media and technology skills include information literacy, media literacy and information/communications/technology literacy. Finally, life and career skills include flexibility and adaptability, initiative and self-direction, social and cross-cultural skills, productivity and accountability and finally, leadership and responsibility (Partnership for 21st Century Skills, 2009). The partnership for 21st century skills categorises these skills into three types:

(1) Learning skills are critical thinking, creative collaborating and communicating.
(2) Literacy skills include information literacy, media literacy and technology literacy.
(3) Life skills, examples flexible, leadership, initiative, social skills (collaboration) and productivity.

The partnership for 21st century skills (P21) was founded in 2002 as a coalition bringing together the business community, education leaders, and policy makers to position 21st century readiness at the centre of US K-12 education, and to kick-start a national conversation on the importance of acquisition of 21st century skills for all students. The P21 advocates for all students to be ready for college, career and citizenship roles along the entire continuum of learning to meet an increasingly diverse, globalized, complex and media saturated society in which the students live (Jacobs, 2010; Schlechty, 2011).

In 2007, the partnership for 21st century skills (www.21centuryskills.com) developed a framework for 21st century learning, which describes the skills that students need to thrive in today's global economy. The Framework is organized into four categories: digital age literacy, inventive thinking, effective communication and high productivity. The six key elements for fostering 21st century skills as identified by the partnership for 21st century skills include (1) emphasis on core subjects, (2) emphasis on learning skills, (3) use of 21st century tools to develop learning skills, (4) ability to teach and to learn in a 21st century context (5) ability to teach and learn 21st century skills and (6) use of 21st century assessments that measure 21st century skills.

The best practices for encouraging teachers and other educational stakeholders to implementing the acquisition of 21st century skills include (a) focus on real-world problems and processes (b) support inquiry-based learning experiences (c) provide opportunities for collaborative project approaches to learning and (d) focus on teaching students how to learn (above "what" to learn). It is essential that every learner should be given an opportunity in the teaching and learning process to acquire the basic knowledge and processes of science as well as the 21st century skills for him/her to effectively live in this technological age. Hence, advocates of 21st century skills favour student-centred methods such as problem-based learning, inquiry-based learning and project-based learning that allow students to collaborate, work on authentic problems and engage with the community (Rotherham & Willingham, 2009).

Today, much success lies in being able to communicate, share, and use information to solve complex problems, in being able to adapt and innovate in response to new demands and changing circumstances, in being able to command and expand the power of technology to create new knowledge. Hence, new standards for what students should be able to do are complementing the basic skills competencies and knowledge expectations of the past. To meet these challenges, schools must be transformed in ways that will enable student's to acquire skills such as the creative thinking, flexible problem solving, collaboration and innovation which they will need to be successful in work and life (Elkins, 2007; Carroll, 2007; Frey & Fisher, 2008; Riddle, 2009; Trilling, 2009).

The 21st century skills are the essential knowledge, capabilities and dispositions needed for the increasingly information-driven and technologically-powered societies (Trilling and Fadel, 2009). Proponents of 21st century learning advocate an expanded set of educational goals, as in the Partnership for 21st century skills (P21) learning framework (2007), for the integration of skills such as critical thinking, problem-solving, and communication into the teaching of core academic subjects such as English, reading or language arts, world languages, mathematics, economics, science, geography, history, government and civics.

Trilling & Fadel (2009) suggested that teachers need to move away from the traditional methods of teaching and bring into the classroom new and innovative approaches to teach the content and lifelong skills. They argue that it is important to utilize a variety of techniques for students to build their own understanding through real world applications and interactions with their peers in group activities.

> *"To be productive contributors to society in our 21st century, you need to be able to quickly learn the core content in field of knowledge while also mastering a broad portfolio of essentials in learning, innovation, technology, and career skills needed for work and life*"(Trilling & Fadel, 2009:16).

Trilling & Fadel (2009) suggested that teachers need to prepare students for job that have not yet been created, for the new products that have not yet been invented, and for the new skills to build towards creativity and innovation.

The principles of effective learning important to 21st century education practitioners include as identified by Elkins (2007), Riddle (2009), Trilling & Fadel (2009) and Triling (2010):

- Authentic learning–learning from real world problems and questions.
- Mental model building –using physical and virtual models to refine understanding.

- Internal motivation –applying multiple learning methods for diverse learning styles.
- Social learning –using the power of social interaction to improve learning impact.
- International learning –using the world around you to improve teaching and learning skills.

The identified teaching strategies that foster students' 21st century skills development (Trilling & Fadel, 2010) are:

- Inquiry based teaching
- Project based teaching
- Collaborative teaching approach
- Use of web technologies

A systematic integration of 21st century skills and content benefit the students linguistically, socially, cognitively and academically (Riddle, 2009; Trilling & Fadel, 2009; Bybee, 2009; Trilling & Fadel, 2010). The 21st century learning initiatives informed by emergent research on how people best learn, leverage emerging technologies (e.g. computers, smart phones, web tools) and embrace the collaborative, participatory learning made possible through the web (Lessig, 2008 and Watson, Gemin & Ryan, 2008). Also, game-based learning, that is learning content through virtual environments enhances student learning. Simulation games in online "virtual" environments can be influential learning tools. Such games give students a chance to take on new identities and skills, virtually into situations in which they can apply knowledge in ways not possible in most students' real lives (Metri Group, 2006 and Carroll, 2007).

Furthermore, project-based learning (PBL) has illustrated significant benefits for students who collaborate on learning activities in contrast with students who work alone. Bell (2010) reported that project-based learning leads to greater self-motivation, as students explore learning activities; they are genuinely interested in the learning activities. Hendry & Viney (2002) indicated that inquiry-based approaches such as problem and project-based learning are better than traditional approach in equipping students beyond the classroom and in their professional and working live (Fisher, 2009; Boix-Mansilla & Jackson, 2011).

Alshannag & Hamdan (2015) showed positive relationship between inquiry-based learning and the 21st century skills and highlighted that low involvement of the students in inquiry-based teaching would hinder 21st century skills.

Quality professional development must be ensured for educators' understanding of the importance of 21st century skills and how to integrate them into daily instruction through a variety of tools for students' acquisition of 21st century skills ([Partnership for 21st century skills, 2009).

2.6 Integration of Information and Communication Technology into Teaching

Technology in Education can be described as the application of technology to any of the processes involved in teaching, learning, communication and management of educational programmes. Technology in education is defined by Hooper & Rieber (1995) as the quantity of technological devices supporting traditional activities in education devices be it anything electronic such as CD players, photocopiers and many more.

Technology enables students to learn in ways not previously possible. Effective integration of technology is achieved when students are able to select technology tools to help them obtain information in a timely manner, analyze and synthesize the information and present it professionally. The technology should become an integral part of how the classroom functions. The impact of multimedia is that students can explore new concepts that are closer to their daily experience and explaining the concept of good science. This is a favourable change from the way of usual thinking to a concrete way of thinking. So this could indirectly increase students' interest in learning science process skills, and thus make the learning process more effective.

The use of technology in education has been growing steadily around the world. Using Nigeria as an example, technology has continued to be a pathway for educationists to improve their teaching methods, to enhance the presentation of materials, to engage students and to provide current and relevant information. Although there was a great influx of technology into the classrooms in the mid-1980s, this explosive growth did not seem to match the growth of technology in the general populace. It has generally been observed that new technology goes to military, the private sector, higher education, and finally public education in that order (Thacker, 2007). This inclusion of technology in the classroom began in earnest around the time the first personal computers hit the market. As educators use technology and more importantly, as strong professional development in the integration of technology in education, they design curriculum with the use technology as a tool to enhance learning in a content area or in a multidisciplinary setting.

The modes of communication have greatly changed because of technology. Information is mostly available to anyone with the right technology. Instant communication around the world is a reality for personal, business and educational applications.

Technology enables students to learn in ways not previously possible. Effective integration of technology is achieved when students are able to select technology tools to help them obtain information in a timely manner, analyze and synthesize the information and present it professionally. Technology should become an integral part of how the classroom functions.

2.6.1 Chemistry Teaching and Information and Communication Technology

Teaching and learning of science subjects especially, chemistry demands more attention because of the difficulties students encounter in learning the subject. The fact that students encounter difficulties learning chemistry is well reported (Acar & Tarhan, 2007; BouJaoude & Barakat, 2000; Chandrasegaran, Treagust, Waldrip & Chandrasegaran, 2009; WAEC 2007, 2011; Opara, 2009). Teaching methods employed by the teachers are another problem facing chemistry teaching and learning. It is opined that most of the problems associated with the teaching of chemistry will be alleviated when new technologies are integrated into the teaching of the subject.

There are different types of technology that can be integrated into teaching and learning to support and enhance learning. Some of the technologies currently being use in the classrooms include communication devices and applications such as cell phones, computers, projectors, interactive whiteboards, various software applications, and the Internet. Availability of some of these technologies at home and in school will go long way to in enhancing learning. Notten and Kraaykamp (2009) stated that science performance is positively affected if there is a positive reading climate and computer availability at school and at home. The innovative methods of the utilization of new technologies in chemistry teaching are based on the advantages of the use of new technologies. They facilitate and advance the work of the teacher and the student in both theoretical and practical aspects. Practical work with the help of new technologies represents simplification of procedures when applying chemicals and laboratory equipment during experiments (Milan & Danijela, 2009). The effective utilization of those applications depends largely on teachers' awareness of, familiarity and ability with these new technologies. According to Onwu and Ngamo (2009), there is the need for chemistry teachers to know exactly how these technologies can be used as teaching and learning tools in chemistry classroom.

Su (2007) made a systematic assessment of students' learning effects and attitudes of chemistry with integrated information communication technologies (ICT). The results showed that multimedia technology can have a facilitating function in the process of learning which helps students acquire a better understanding of targeted chemistry concepts and promotes a positive attitude toward chemistry learning. Multimedia technology provided powerful means for fostering chemical understanding. According to Su (2007), multimedia technology plays a vital mediating role in helping students overcome many difficult and abstract concepts; and it appears to have potential benefits for integrating the classroom teaching, group study, and individual meaning making.

2.6.2 Challenges of ICT Integration in the Classroom

Due to ICTs importance in the education now and in the future, identifying the obstacles to the integration of these technologies in schools would be an important step in improving the quality of teaching and learning. Several factors have been reported as constraints to integration of ICT in the classroom. According to Walker (2011), critical factors for successful integration included moderate technical skills, self-motivation to engage in instructional technology, supportive peer communication channels and flexibility in approaches for planned lesson.

Successful integration of ICT in the school system depends largely on the availability, competence and the attitude of teachers towards the role of modern technologies in teaching and learning. Research studies have shown that most secondary schools have either insufficient or no ICT tools to cater for the ever increasing population of students in the schools and where they are available, they are by implication a matter of out-of-bounds to the students (Chattel, 2002; Cheng, 2003; Chiemeke, 2004). Fakeye (2010) also found in a study carried out in Ibadan that most of the schools covered in the study do not have computers, hence are not connected to the internet. Fakeye, (2010) added that those who have computers do not use them for teaching but solely for administrative purposes. In another study by Okwudishu (2005), the unavailability of some ICT components in schools hampers teachers' use of ICTs. Lack of adequate search skills and of access points in the schools were reported as forces inhibiting the use of internet by secondary school teachers (Adoni & Kpangban, 2010). Following similar trend, Akindoju, Banjoko, & Avoseh, (2011) identified the insufficient quantity of computer hardware and software as another major factor inhibiting integration of ICT in the classroom and that this is due to budgetary constraints. Ozoji (2003) reported in a study that most secondary schools do not have software for the computer to function. One of the unity schools has five computers against a population of 900 and no internet software was installed. The facilities are grossly inadequate for any meaningful teaching or learning to take place.

On teachers' competence, teachers in Nigerian secondary schools are not competent in basic computer operation and in the use of generic software (Yusuf, 2005), even though they have positive attitude towards the integration of ICT in Nigerian secondary schools. Moving computers in and out of a classroom is time consuming and significantly inhibits their use. Moving students to a "computer lab" also has several constraints; the two major ones being that the typical computer laboratory is too small and that teachers must compete for limited laboratory time. Another major constraint to an established computer education programme is the area of provision for continuity where students are unable to receive continued access to the computer after the transfer of a teacher hence; many innovations introduced at a school may be lost after that time. An example is when skilled staff is transferred out of the school taking with him much of the expertise built up in the school over time. Without continuity of skill use in the school, new teachers are unlikely to make effective use of computers and students will be denied access. Continuity of the programme is essential if equitable long-term access is to be achieved in schools with significant number of students. The more remote the location, the greater the difficulties and consequently, the students attending such schools, when compared to their counterparts in the city, can be significantly disadvantaged.

2.7 Software development and use in chemistry teaching

There have been many strives for innovation in teaching and learning Chemistry using computer software. Today's Chemistry education teaching is not perfect; it has two serious problems that can be solved with the advanced computer technology. One, the traditional Chemistry classroom teaching, no matter how hard the teachers try to teach students the basic chemical concepts and principles before the chalkboard, they still complain that the chemistry class is very confusing and boring. Also, the traditional chemistry laboratories are very dangerous, expensive and environmentally hazardous. Most chemicals in the laboratories are explosive, highly toxic and carcinogenic substances. This strongly requests the students to protect themselves from accidental skin, eye and respiratory contact. Meanwhile, traditional standard laboratory equipment is inaccessible to the students with disabilities.

As technology spurs scientific advance, it also advances research on instruction and re-defines the goals for the science course. An information technology learning environment provides students with swift access to new information (Su, 2007) and its reasonable application can make teaching more diversified, flexible and effective (Dawson, Forster, & Reid, 2006). Software tools are widely used today in the classroom and are proving to be very effective teaching aids. One of the benefits of software tools is that they offer a means for visualization of abstract concepts and ideas. If used properly software tools can improve teaching efficiency in many instances. As a teaching tool, computer software can provide a new way to link abstract concepts with tangible visualizations. Specialized computer software offers students the option of self-learning and can also be instrumental in motivating them to learn abstract engineering concepts. According to Dunnivant (2013), people are visual learners, therefore, appropriately designed software materials can help students build mental links to strengthen their logical framework of conceptual understanding and to achieve a mastery level understanding of chemical concepts" (Arasasingham, Taagepera, Potter, Martorell, & Lonjers 2005).

This part of literature surveyed some of the software available for chemistry teaching. According to Chibiao (2013), there is web- based and non web-based chemistry teaching software. Novel Web-based chemistry teaching software (NWBCTS) developed by Chibiao in 2013 covers all the main branches of chemistry education and they are General Chemistry, Inorganic Chemistry, Organic Chemistry, Analytical Chemistry, Polymer Chemistry and Biochemistry. Classroom chemistry teaching and lab experiments teaching are the focus on each of the branches. Fun graphics and sounds clearly illustrated concepts and principles, and help students to understand and consolidate chemistry knowledge easily in the classroom chemistry teaching while the laboratory experiment part is built based on an interactive java-applet based graphical simulation of the actual laboratory experiments and a rich chemistry experiment database. Simulated experiment software will allow students to perform experiments on any computer at any possible places: home, computer labs and library.

Using this software, students can step-through the actual laboratory procedure while interacting with animated equipment in a way that is similar to the real laboratory experience. Students can also be able to choose experimental variables such as reactants, concentration, and temperature repeating the experiments under different conditions. In this way, dangerous and difficult experiments could be performed safely on the computer without toxic fumes, broken glass, or costly disposal. Moreover, they may be a good alternative for students with severe disabilities who would not otherwise be able to participate in the laboratory. The novel WBCTS software can be installed in the chemistry computer laboratory, and can also be published in the internet which can enable the long-distance students to have access to the simulation classroom and laboratory.

Conversionoes software developed by Ellis (2009) is a play on words between “conversion” and “dominoes”. Conversionoes is a web-based application that is easily accessible. It is developed to promote conceptual and visual understanding of high school chemistry students in Dimensional Analysis which is also referred to as Unit Conversions, Conversion Factors, Factor-Label Method or the Unit Factor Method. The conversionoes employed a problem-solving method of manipulating unit measures algebraically to determine the proper units for a quantity. In general, dimensional analysis involves analyzing the units in a problem and is the most popular approach for solving chemistry problems in high school chemistry (TMW Media Group, 2004).

Conversionoes consists of three main elements: Conversionoes Game, Smaller or Larger and Dimensional Analysis. The Conversionoes game is based on the traditional game of dominoes but uses conversion factors as the domino pieces instead of the traditional numbering. The purpose of the Conversionoes game is to expose students to units of measurement with respect to a specific category of the International System of Units (SI) (e.g., length and mass) and to show the linking aspect of units. The Smaller or Larger element of the software was designed primarily to help student’s visual understanding of units, although it required the use of their conceptual understanding as well. In terms of how Smaller or Larger is played, the students are given two units of measurement after which they have to determine which element is larger or smaller. Once a student enters a decision, he or she would see how the units are represented in household items and which of those items/units is larger or smaller.

The final element of the software allows students to use Conversionoes to help them solve dimensional analysis problems. There are three levels of problems ranging from Level One featuring more simplistic problems to Level Three with multiple-step dimensional analysis problems. Students are allowed to click on a “Hint” button to see video tutorials that will help them (1) put their final answer in significant figures, (2) put their final answer in scientific notation, (3) learn how to use a scientific or graphical calculator to calculate their final answer and (4) provide strategies on how to solve dimensional analysis problems. As students successfully complete a level with at least 90% accuracy, they are able to print a level-specific certification document for their records (e.g., Dimensional Analysis Level One Certified).

The Atom Builder is the software for chemistry teaching developed by Ray Le Couteur in 2004. It is one of the interactive software simulations designed to teach basic chemical concepts like atoms, electron configuration and bonding. It is not free but a trial version is made available for 30 days. This Chemistry teaching software simulates the building of any of the first 20 atoms (up to calcium) on screen. It is sequentially arranged to learn how atoms are formed from electrons, how protons and neutrons are arranged and how the electrons are arranged in shells or energy levels. It includes a reference section to support students' learning with basic facts and information. The simulation is interactive - questions that have to be answered along the way. If students are stuck, they will need to go to the reference sections which provide background information on atomic structure.

EnviroLab is Chemistry software developed by Frank Dunnivant in 2013. It is a chemistry software package that helps visual learners supplement their in-classroom learning by simulating chemistry labs. It allows students to re-enact a lab experience on the computer. Through animation, students simulate the lab and can do almost everything that students physically do in a real laboratory experiment. The purpose of EnviroLab is not to replace the whole laboratory experience but to allow students to walk through and familiarize themselves with the laboratory before the real laboratory experiment.

Chemlab is a virtual laboratory software. Model ChemLab is both an interactive simulation and a lab notebook workspace with separate areas for theory, procedures and student observations. Commonly used lab equipment and procedures are used to simulate the steps involved in performing an experiment. Users step-through the actual lab procedure while interacting with animated equipment in a way that is similar to the real lab experience. The areas of coverage include, acid/base reactions, balance lab, bond lab, cations reactions, electrochemistry, equilibrium, flame lab, fractional crystallization, fractional distillation, gas laws, gravimetric analysis, kinetics, nuclear chemistry, redox reactions, stoichiometry, thermal chemistry, volumetric analysis, water quality, weak acid titration among others.

Chemistry Courseware Consortium: the chemistry courseware consortium produces software for teaching chemistry at higher education level. Four projects have been chosen: Basic Chemistry, Theoretical Methods, Spectroscopy, and Shapes of Molecules. Software is offered at cost, and on their FTP server, the only freeware found is a Periodic Table Quiz and a Software Sampler.

Oyelekan & Olorundare (2009) developed and validated a computer instructional package on electrochemistry for secondary schools in Nigeria. Based on the fact that electrochemistry is one of the topics responsible for students' poor performance in School Certificate Chemistry examinations in Nigeria. The main purpose of the research was to transform the electrochemistry content of the Nigerian secondary school chemistry curriculum into computer software, and then package it into a CDROM which could be used for teaching and learning of electrochemistry. The results obtained from the analyses of the data gathered in this research indicated that the content of the Electrochemistry Computer Instructional Package (ECIP) as developed covered the electrochemistry aspect of the Nigerian secondary school chemistry adequately, and that it was also sequentially arranged. The result further showed that the package conformed to acceptable standards of educational technology. Besides, the performance level of students when taught using ECIP was very good as it enhanced the understanding of the topic.

At this present age of 21st century when technology has been integrated into the curriculum, Chemistry as a central science cannot be left out. Some of the software developed for the improvement of teaching and learning chemistry at all educational levels in and outside Nigeria is compiled. However, the list is not exhaustive, as more software is being developed on a daily basis. Software development in Chemistry has been observed to be low in Nigeria. The software developed and used so far has no link particularly to any teaching method.

2.8 Models of Instructional Package Development

Designing an effective instructional plan requires some systematic planning taking into account some critical issues which may be referred to as elements of instructional designs. Instructional Design is the practice of creating instructional experiences which make the acquisition of knowledge and skill more efficient, effective and appealing. The process consists broadly of determining the current state and needs of the learner, defining the end goal of instruction and creating some "intervention" to assist in the transition. Ideally the process is informed by pedagogically (process of teaching) and andragogically (adult learning) tested theories of learning and may take place in student-only, teacher-led or community-based settings. The outcome of this instruction may be directly observable and scientifically measured or completely hidden and assumed.

Instructional design model can also be referred to as the systematic process to planning and validating instruction for use, a good model should run right from the preparatory level to the evaluation level.

Adegbija (2007) opined that a good model for instructional planning should be cyclic and dynamic in nature. Here are some Instructional Design Models

1. The ADDIE Model
2. The ASSURE Model
3. The Gerlarch and Ely Instructional Design Model
4. The Dick and Carey Systems Approach Model
5. Kemp Model
6. Gagne Model
7. Donald Kirk Patrick Evaluation Model (1999)
8. Instructional Development Learning System (IDLS)
9. Instructional Video Production Process Model (IVPPM) Osho (2014).

Some of these models are explained in details..

2.8.1 The ADDIE Model of Instructional Design

The ADDIE model is actually a frame work that lists the generic process traditionally used by instructional designers and training developers (Morrison, 2010). ADDIE Model revolves round five stages which first letter of each form the acronym –ADDIE.

The five stages — Analysis, Design, Development, Implementation, and Evaluation — represent a dynamic, flexible guideline for building effective training and performance support tools The ADDIE model was initially developed by Florida State University to explain –the processes involved in the formulation of an instructional systems development

(ISD) program for military inter-service training that will adequately train individuals to do a particular job and which can also be applied to any inter-service curriculum development activity. The model originally contained several steps under its five original phases (Analyze, Design, Develop, Implement and Evaluation), whose completion was expected before movement to the next phase could occur. Over the years, the steps were revised and eventually the model itself became more dynamic and interactive than its original hierarchical rendition, until its most popular version appeared in the mid-80s, as we understand it today.

Phases of ADDIE Model of Instructional Design Analysis Phase

In the analysis phase, the instructional problem is clarified; the instructional goals and objectives are established. The learning environment, learner's existing knowledge and skills are identified. Below are some of the questions addressed during the analysis phase:

- Who are the learners and what are their characteristics?
- What is the desired new behavioural outcome?
- What types of learning constraints exist?
- What are the delivery options?
- What are the pedagogical considerations?
- What are the Adult Learning Theory considerations?
- What is the timeline for project completion?

Design Phase

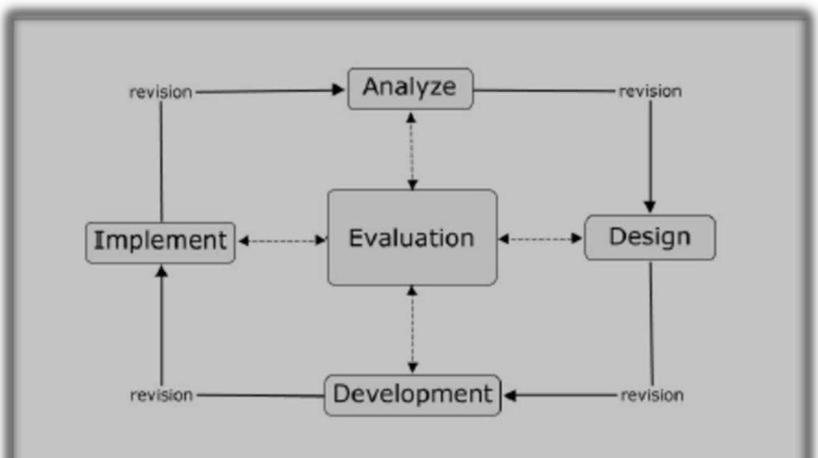
The design phase deals with learning objectives, assessment instruments, exercises, content, subject matter analysis, lesson planning and media selection. The design phase should be systematic and specific. Being systematic means a logical, orderly method of identifying, developing and evaluating a set of planned strategies targeted for attaining the project's goals. To be specific means that each element of the instructional design plan needs to be executed with attention to details.

These are steps involved in design phase:

- Document the project's instructional, visual and technical design strategy
- Apply instructional strategies according to the intended behavioural outcomes by domain (cognitive, affective, and psychomotor)
- Design the user interface and/or user experience
- Create prototype
- Apply visual design (graphic design)

Development Phase

The development phase is where instructional designers and developers create and assemble the content assets that were blueprinted in the design phase. In this phase, storyboards and graphics are designed. If e-learning is involved, programmers develop and/or integrate technologies. Testers perform debugging procedures. The project is reviewed and revised according to the feedback received.



ADDIE Model

Figure 2.1: The ADDIE Model of Instruction, (Morison 2010)

Implementation on Phase

During the implementation phase, a procedure for training the facilitators and the learners is developed. The training facilitators should cover the course curriculum, learning outcomes, method of delivery, and testing procedures. Preparation of the learners includes training them on new tools (software or hardware) and student registration. Implementation is also evaluation of the design.

This is also the phase where the project manager ensures that the books, hands-on equipment, tools, CD-ROMs and software are in place and that the learning application or website is functional.

Evaluation Phase

The evaluation phase consists of two parts: formative and summative. Formative evaluation is present in each stage of the ADDIE process.

2.8.2 The Assure Model

The ASSURE Model is an ISD (Instructional System Design) process that was modified to be used by the teachers in the regular classroom. The ASSURE Model is a guide for planning and conducting instruction that uses media. This model is attributed to Heinich, Molenda, Russell, and Samldino from Instructional Media and Technologies for Learning. The ISD process is the one in which teachers and trainers can use to design and develop the most appropriate learning environment for their students. This process can be used in writing lesson plans and improving teaching and learning.

The ASSURE model incorporates Robert Gagne‘s events on instruction to assure effective use of media in instruction. A – Analyze Learners

S – State Standard and Objective

S – Select Strategies, Technology, Media and Materials

U – Utilize Technology, Media and Materials

R – Require Learners‘participation

E- Evaluate and Revise

To ASSURE good learning outcome, it is not one single thing that a teacher or designer must consider but, there are areas of emphasis (Sharon Smaldino).

Analyze Learners

To start with, ASSURE looks at the learners in detail. There is no plan or designs of instruction that is effective unless the designer first look at the learners. A good teacher or instructional planner/designer should analyze the learners‘characteristics.

The first step in planning is to specifically identify the audience. The audience can be students, new teachers, members of an organization, a youth group and many others. The audience must be identified to select the best medium to meet the objectives set. The audience can be analyzed in terms of their general characteristics (grade level, age, sex, mental, emotional, physical or social problems, socio-economic status and so on) and specific entry competencies (prior knowledge, skills, and attitudes about the topic) and learning styles (visual, musical, verbal, logical, and many others).

State Objectives

The next step in planning is to specifically state the objectives for the instructional experience. Objectives are the learning outcomes, that is, what will the student get out of the lesson? Hence, they must be stated in behavioural terms of what the learner (not the teacher or presenter) will be able to do as a result of instruction. Objectives typically contain four basic parts:

- Audience-who your learners are?
- Behaviour to be demonstrated
- Conditions under which the behaviour will be observed
- Degree to which the learned skills are to be mastered.

Select methods, media and materials

Once you know your audience and have a clear idea of what they should get out of the lesson, then it is time to select the appropriate method for the given learning task, select available materials, modify existing materials or design new materials to help accomplish this task.

Utilize media and materials

Now you must decide how the media, materials and technology must be used to carry out your methods. It is important to preview the materials before using them. If you decide to use electronic equipment, practice using the equipment in advance to be sure everything works. If all is not well, (especially if the equipment malfunctions) ensure that you have a plan B. It is also important to practice the lesson itself before it is implemented. Next, prepare the room and make ready the necessary equipment and facilities. Learners should be prepared for the learning experience. Then, conduct the instructional experience.

Require Learner Participation

It is important to note that students learn best when they are actively involved in the learning experience. Whatever your teaching strategy, be sure to incorporate questions and answers, discussions, group work, hands-on activities and other ways of getting students actively involved in the learning of the content. One should try to avoid lecturing for lengthy periods. It is very important to listen to your audience and allow them to become aware of the content.

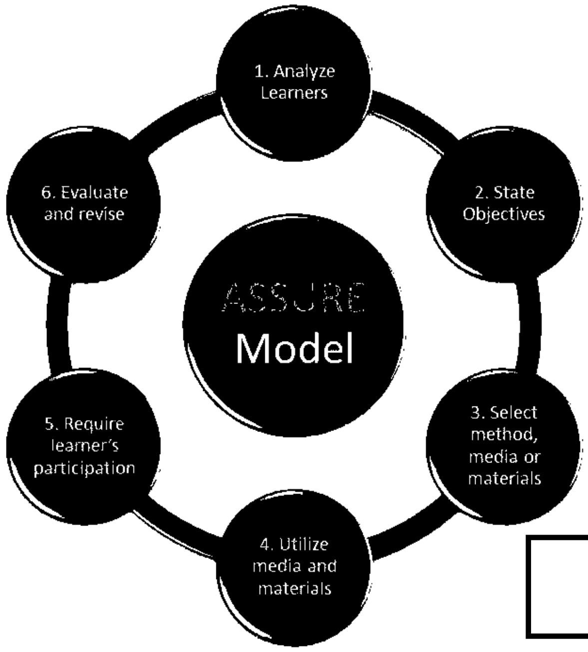


FIGURE 2.2: THE ASSURE MODEL; E. WILLIAM CLYMER (2007)

Allow them to construct knowledge as opposed to trying to "teach" them knowledge. Feedback must be provided before any type of evaluation is administered.

Evaluate and Revise

This last stage is often overlooked but it is the most important of all. After instruction, you must evaluate the entire instructional process. You must reflect upon the lesson, the stated objectives, the instructional strategy, the instructional materials and the assessment and determine if these elements of the lesson were effective or if one or more of them need to be changed. If there are discrepancies between what you intended and what actually happened during the lesson, make appropriate revisions before using the lesson again.

2.8.3 Gerlach and Ely Instructional Design Model

The Gerlach and Ely model is such a classroom model created by Vernon S. Gerlach and Donald P. Ely, in 1980. They decided that there was a great need for school teachers to have a comprehensive overview of teaching and learning. For this reason, the authors determined ten most necessary instructional elements and created a step-by-step guidance for instructional planning.

Gerlach and Ely model was constructed based on two rationales: The systematic approach and Pragmatism approach. Throughout the model, the role of the teacher is a coordinator of learning resources rather than a traditional presenter of information of knowledge. According to Ely (1980), he asserted that this model has stood the test of time and serves the classroom teacher well.

The Ten Instructional Elements Itemized by Gerlach and Ely

1. **Specification of instructional goals or objectives or aims**: This is the first element itemized by Gerlarch and Ely, in this stage, the teacher list the objectives to be achieved at the end of the lesson, that is, the intended learning outcome.

2. **Specification/ Selection of Content**: The content is the total body of knowledge the teacher intend to impact on the learners. The teacher carefully selects the content having consulted the syllabus/curriculum and also the learner‘s characteristics in order to address their needs. He then disseminates to the learners using a specific methodology.

3. **Assessment of Learners Entry Behaviour/ Previous Knowledge**: The teacher assesses the students‘ previous knowledge by asking questions on their previous experience relating to the new topic. This helps him to start his teaching from known to unknown and from simple concepts to complex ones, also from empirical to abstract.

4. **Determination of Instructional Strategy:** The teacher determines and deploys the

most suitable instructional technique that suits the learner‘s characteristics, subject, and content.

5. **Organization of Learners into Group:** The teacher divides the learners into groups and allots activities for them.

6. **Allocation of Time:** the teacher create a regular timing schedule for each group, in order to supervise, coordinate, direct and inspect the activities of each group.

7. **Allocation of Learning Space**: the teacher create a conducive learning environment for each group, such that they can work at their own pace and simultaneously.

8. **Selection of Appropriate Instructional Material or Resources**: The teacher selects suitable material(s) to aid the learning. The teacher can use the adaptive, imitative or creative approach in designing his own instructional material to suits its purpose.

9. **Evaluation of Instructional Outcome or Performance:** The teacher appraises the learners‘ learning outcome by asking questions based on his predetermined instructional objective as stated in step 1 above.

10. **Analyses of Feedback/Responses:** The result of the evaluation is compared with the expected learning outcome (stated objectives). If it meets the expectation, the teacher moves on to the next topic or content, else, the carefully re-examine the objectives and start all over.

Thus making the Gerlach and Ely model a cyclic process, just like the ADDIE and ASSURE models. Gerlach and Ely model of instructional Design can however be diagrammatically explained in figure 2.3 below.

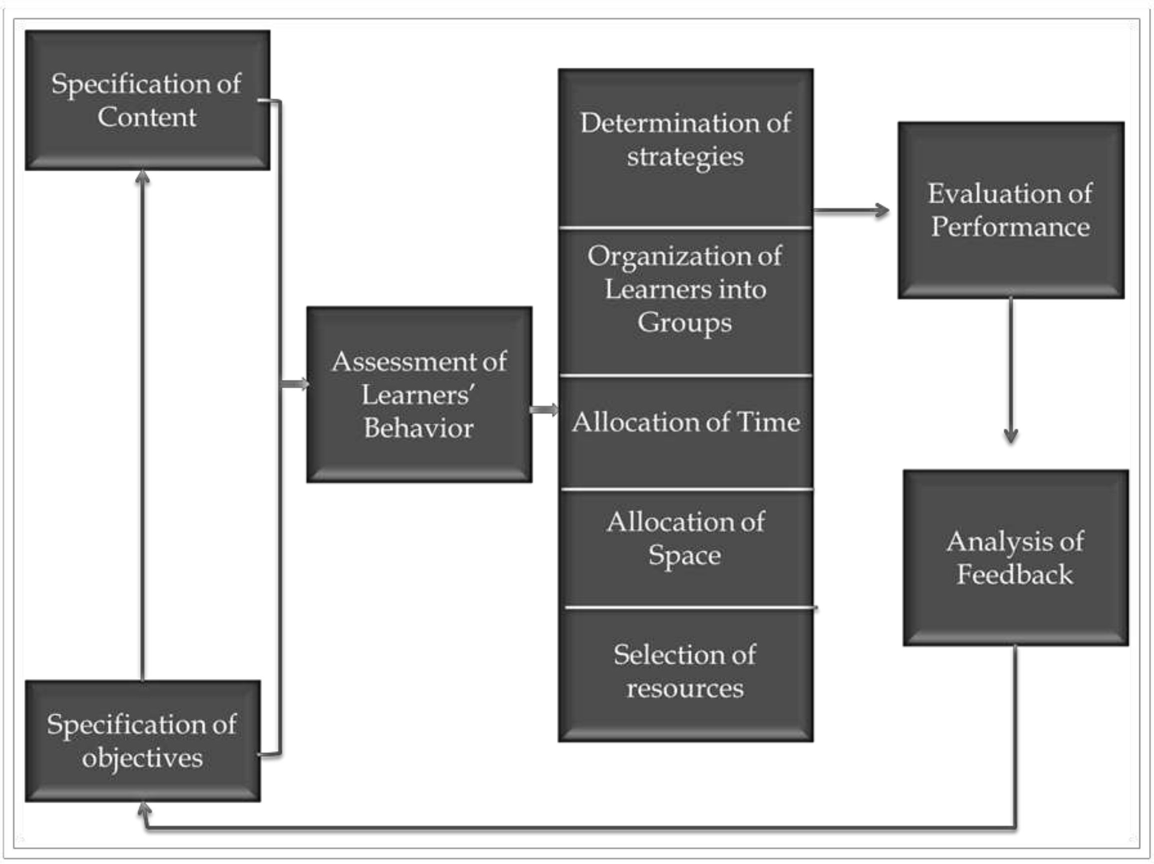


Figure 2.3: The Gerlach and Ely Model of Instructional Design (1970)

2.8.4 Donald Kirkpatrick Levels Of Evaluation (1994)

Assessing training effectiveness often entails using the four level model developed by Donald Kirkpatrick (1994). According to this model, evaluation should always begin with level one, and then, as time and budget allows, should move sequentially through levels two, three, and four. Information from each prior level serves as a base for the next level's evaluation. Thus, each successive level represents a more precise measure of the effectiveness of the training program Kirkpatrick's four levels are designed as a sequence of ways to evaluate training programs.

As you proceed through each of the levels, the evaluation becomes more difficult and requires more time and each level provides more information. Kirkpatrick notes in his book, 'Evaluating Training Programs (Third Edition)' that none of the levels should be bypassed simply to get to level that the trainer considers the most important.

Kirkpatrick's Four Levels of Evaluation

1. **Reactions:** Just as the word implies, evaluation at this level measures how participants in a training programmes react to it. It attempts to answer questions regarding the participants' perceptions - Did they like it? Was the material relevant to their work? This type of evaluation is often called a smile sheet. According to Kirkpatrick (1994), every program should at least be evaluated at this level to provide for the improvement of a training program. In addition, the participants' reactions have important consequences for learning (level two). Although a positive reaction does not guarantee learning, a negative reaction almost certainly reduces its possibility.

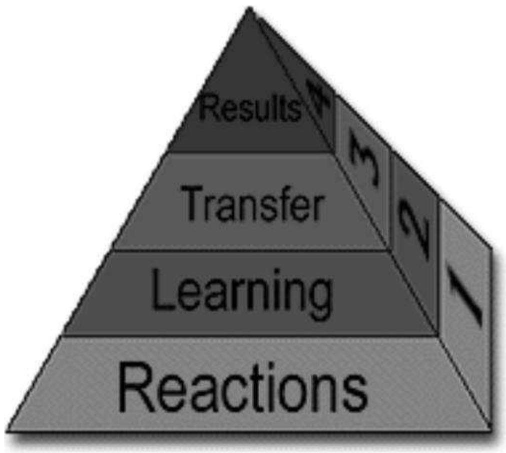


Figure 2.4: Kirkpatrick's four levels of evaluation (1994).

2. **Learning:** To assess the amount of learning that has occurred due to a training program, level two evaluations often use tests conducted before training (pre-test) and after training (post-test). Assessing at this level moves the evaluation beyond learner satisfaction and attempts to assess the extent students have advanced in skills, knowledge, or attitude. Measurement at this level is more difficult and laborious than level one. Methods range from formal to informal testing to team assessment and self-assessment. If possible, participants take the test or assessment before the training (pre-test) and after

training (post-test) to determine the amount of learning that has occurred.

3. **Transfer:** This level measures the transfer that has occurred in learners' behaviour due to the training program. Evaluating at this level attempts to answer the question - Are the newly acquired skills, knowledge, or attitude being used in the everyday environment of the learner? For many trainers this level represents the truest assessment of a program's effectiveness. However, measuring at this level is difficult as it is often impossible to predict when the change in behaviour will occur, and thus requires important decisions in terms of when to evaluate, how often to evaluate, and how to evaluate.

4. **Results:** Level four evaluation attempts to assess training in terms of business results. In this case, sales transactions improved steadily after training for sales staff occurred in April 1997. Frequently thought of as the bottom line, this level measures the success of the program in terms that managers and executives can understand - increased production, improved quality, decreased cost, reduced frequency of accidents, increased sales, and even higher profits or return on investment. From a business and organizational perspective, this is the overall reason for a training program, yet level four results are not typically addressed. Determining results in financial terms is difficult to measure, and is hard to link directly with training. Osho’s Model will be used because;

- It is indigenous and appropriate for classroom design model for a digital age.

2.9 Appraisal of Literature Review

The available studies reviewed on integration of technology into chemistry teaching focused mainly on using technology tools, devices and software to supplement traditional teaching and their effect on students’ academic achievement, science process skills and attitude to Chemistry. Software/courseware developments in Chemistry are majorly foreign and most of the studies reviewed on integration of Information Technology into instruction (Chibiao, 2013; Dunnivant 2013; Ellis, 2009; Su, 2007; Oyelekan and Olorundare, 2009) did not integrate information technology into a particular teaching strategy.

Also, most literature reviewed on effect of information technology instruction did not measure problem solving skills and 21st century skills. None of the studies examined the influence of school type. All these necessitate the need to adopt an instructional system design (ISD) model (in this study ASSURE model) to integrate information technology into teacher demonstration and guided discovery teaching strategies and make empirical investigations on the effectiveness on chemistry students' conceptual understanding, problem solving skills, acquisition of science process skills and 21^{st} century skills.

CHAPTER THREE

RESEARCH METHODOLOGY

This chapter describes the research design, the population, sample and sampling techniques for the study as well as variables, research instruments, validity/reliability of the instruments and procedures for the development and the use of the IT-Integrated Teaching Strategies Packages in a quasi-experimental study.

3.1 Research Design

The study adopted a pre-test, post-test non-equivalent control group quasi-experimental research design with a 4×2×2 factorial matrix to determine the effectiveness of two IT-integrated teaching strategies (guided discovery and teacher demonstration) on secondary school students' conceptual understanding (macroscopic, microscopic and symbolic levels), problem solving skills (prior knowledge, linkage and problem recognition skill), acquisition of five science process skills (observing, classifying, measuring, predicting and inferring) and five 21st century skills (ICT rating, communication, critical thinking, collaboration and leadership). There were also two control groups taught with Teacher Demonstration Strategy and Guided Discovery approach. So, in this study, there are two experimental conditions (IT-Integrated Teacher Demonstration (ITD) and IT-Integrated Guided Discovery (IGD)) and two control conditions (Teacher Demonstration (TD) and Guided Discovery approach (GD)).

The Quasi-Experimental Research Design adopted consists of two experimental groups (Information Technology-integrated Teacher Demonstration Strategy (ITD) and Information Technology-integrated Guided Discovery Strategy (IGD)) and two control groups (Teacher Demonstration Strategy (TD) and Guided Discovery (GD) strategy. It analysed the effects of Information Technology-integrated strategies on Chemistry students' learning outcomes (Conceptual understanding, Problem solving skills, Science process skills and 21st century skills). The design features are represented in Table 3.1 below:

Table 3.1: Pretest – Posttest Quazi Experimental Research Design

Groups	Pre-test	Treatment	Post-test
Experimental group 1(E_1)	O_1	X_1	O_2
Control group 1 (C_1)	O_3		O_4
Experimental group 2(E_2)	O_5	X_2	O_6
Control group 2 (C_2)	O_7		O_8

Key:

O_1 = experimental group 1 pre-treatment assessment

X_1 = experimental group I treatment using ITD package

O_2 = experimental group 1 post-treatment assessment

O_3 = control group 1 pre-treatment assessment

O_4 = control group 1 post-treatment assessment

O_5 = experimental group 2 pre-treatment assessment

X_2 = experimental group 2 treatment using IGD package

O_6 = experimental group 2 post-treatment assessment

O_7 = control group 2 pre-treatment assessment

O_8 = control group 2 post-treatment assessment

The design consisted of four groups (2 experimental and 2 control groups). All the groups were given pre-test ($O_{1,}$ O_3, O_5 and O_7 as pre-treatment assessment. The experimental groups were exposed to treatment (X_1 and X_2) using Information Technology-integrated teaching strategies (ITD and IGD). Participants of the control groups were subjected to no Information Technology-integrated teaching strategy except for the use of Teacher demonstration and Guided discovery strategies. All the groups were later assessed using post-test treatment (O_2, O_4, O_6 and O_8).

3.2 Variables in the study

Independent variables: Instructional strategy manipulated at four levels: (i) IT-Integrated Teacher demonstration (ITD) strategy, (ii) IT-Integrated guided discovery (IGD) strategy, (iii) Guided discovery strategy (GD) and (iv) Teacher demonstration (TD) strategy.

Dependent variables: (i) Conceptual understanding, (ii) Problem solving skills, (iii) Basic science process skills and (iv) 21st century skills acquisition.

Moderator variables: (i) Gender: male and female and (ii) School type: private and public.

These are summarised in Figure 3.1 as shown:

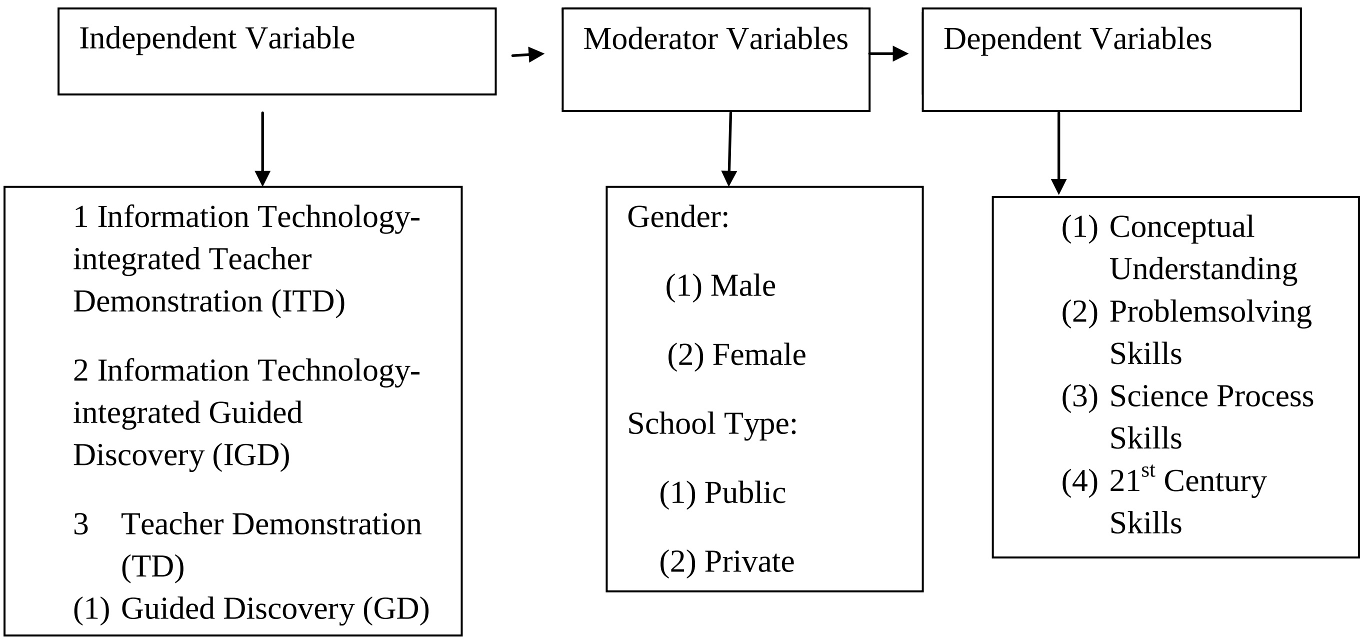


Figure 3.1: Schematic Diagram of the Variables in the Study

3.3 Population of the study

The population for this study consisted of all the Senior Secondary School 2 (SSS 2) chemistry students in Lagos State, Nigeria. SSS 2 students were considered appropriate for the study because they have studied chemistry for at least one year at the senior secondary school level. Furthermore, the commonly reported difficult chemistry topics from the literature selected for this study (the mole concept, rates of reactions, electrolysis and oxidation and reduction) are in the SS2 curriculum.

3.4 Sample and Sampling Techniques

The sample for the study was four hundred and forty-six (446) Secondary School two chemistry students (SS 2). There are six Education Districts in Lagos State. Simple random sampling method was used to select two (Districts II and III) out of the six Education Districts. A purposive sampling technique was used to select public and private schools from the two Education Districts. The criteria for selecting the schools are:

- (i) presence of a well-equipped chemistry laboratory
- (ii) availability of ICT resources for teaching
- (iii) availability of professionally qualified teachers.
- (iv) willingness of the required chemistry teachers in the school to participate in the study and
- (v) the schools must be co-educational

Out of twenty (20) public schools (13 from District II, 7 from District III) and fourteen (14) private schools (7 from each district) that satisfied the criteria set for the selection, 8 public and 4 private schools were randomly selected. Seven (7) schools were selected (2 private and 5 public) from Education District II and five (5) schools (2 private, 3 public) from Education District III using proportionate random sampling. The selection was done to allow for equal representation of the schools in the four treatment groups. The sampled schools were randomly assigned to the treatment group (see appendix XII).

Intact classes were used for the study. Each of the schools sampled has one SS 2 chemistry class therefore; only one teaching strategy was used per school. The total number of students in the twelve schools which completed the pre- and post-tests were 446.

Table 3.2: Distribution of Students Sample by Treatment, School Type and Gender

Treatment Group		Public		Private		Total
	Schools	Male	Female	Male	Female	
IT-Integrated Teacher Demonstration(ITD)	3,8 & 9	46	39	10	8	103
IT-Integrated Guided Discovery (IGD)	2, 7 & 11	60	10	8	5	83
Guided Discovery (GD)	1, 10 & 12	55	41	14	14	124
Teacher Demonstration (TD)	4, 5 & 6	53	53	18	12	136
Total		214	143	50	39	446

Table 3.2 shows the distribution of the sample by treatment, school type and gender. The sample was four hundred and forty-six (446) comprising of 264 male and 182 female. 103 of the sample were taught using IT-Integrated Teacher Demonstration strategy, 83 were taught using IT-Integrated Guided Discovery. 124 students were taught using Guided Discovery while, 136 were taught using Teacher Demonstration strategy.

3.5 Research Instruments

Four research instruments were used for the collection of data in this study. In addition, two teaching software packages were developed and employed in the study to engage the students in teaching and learning processes (IT-integrated teaching packages (ITD and IGD)). There are four (4) Operational Guides, one for each of the strategies (OGITD, OGIGD, OGTD and OGGD). The four research instruments used are as follows:

3.5.1 The Chemistry Conceptual Understanding Test (CCUT): The CCUT was developed by the researcher and has two sections. Section A; provided demographic information such as gender, school type and so on. While, section B contained eight (8) open-ended essay questions comprising two questions on the following topics: Mole concept, Rates of chemical reactions, Redox reactions and Electrolysis. There were three sub-questions in each question, structured to determine the students' conceptual knowledge at macroscopic, microscopic and symbolic levels. The questions were selected from past WAEC question papers (WAEC, 2008, 2009, 2010). Each of the open-ended questions carries 3 marks (1 mark for each of the levels of conceptual understanding). The total mark is 24. (See appendix I). The marking guide for conceptual understanding test can be seen in appendix V.

The Problem Solving Skills Test (PSST)

The Problem-Solving Skills Test (PSST) has two sections, A and B adopted from past WAEC question papers (WAEC, 2008, 2009, 2010, 2011 and 2012). Section A required demographic information from the respondents such as gender, school type and so on. While Section B is an eight (8)-item free response problem test. There are two items in the test for each of the four SS II chemistry topics selected for the study. Respondents were required to record all the details of their thinking processes as they solve each of the problems. This was to determine the problem solving skills of respondents under the 3 blocked skills of prior knowledge (PK), Linkage (L) and problem recognition skill (PRS) (Appendix II). Each block skill has 1 mark obtainable. So, 1 question item has a total mark of 3. Therefore, the total mark for the eight questions is 24. The marking guide for the problem solving skills test is shown in appendix VI.

The Science Process Skills Acquisition Test (SPST)

The Science Process Skills Acquisition Test (SPST) has two sections; A and B. Section A which was constructed by the researcher contains hands-on activities from each of the basic science process skills considered (observing, measuring, classifying, predicting and inferring). Each of the skills has four simple activities to be carried out by students. Each simple activity was scored 1 mark. Total mark in this section is 20.

Section B is a 25 item multiple-choice test adapted to measure the respondents' acquisition of the five basic science process skills: observing, measuring, classifying, predicting and inferring with five questions on each basic science process skill. Total mark in this section is 25. The total mark obtainable for science process skills test is 45 (see appendix III).

The 21st Century Skills Acquisition Test (21st CST)

The 21st Century skills acquisition test investigated respondents' critical thinking, communication, collaboration, ICT literacy and leadership skills. The instrument was adapted from Coulson (2009). In the 21st Century skills test, respondents are to assess themselves on all the skills. The self-assessment test for each skill contains five written statements, which the students are to use in rating themselves with the rating scale of always, sometimes and never. The rating scale of always, sometimes and never was scored 2, 1 and 0 mark(s) for leadership skill. I have trouble with this, I do this reasonably well and I see this as a strength of mine was scored 1,2, and 3 mark(s) for collaboration. Poor, below average, average, above average and excellent was scored 1, 2, 3, 4 and 5 mark(s) as rating scale for ICT Scale Questionnaire. Communication skills test rating scale of; most of the time, often, sometimes, rarely and never was scored 1, 2, 3, 4 and 5. The critical thinking test contained five questions of a multiple-choice type that require knowledge of chemistry (or science) to answer them correctly. Each correct answer in critical thinking test attracts 1 mark. Therefore, the total mark obtainable for critical thinking test is 5 marks. The total mark obtainable in the 21st century skills test is 80 (see appendix IV).

3.6 Treatment Packages

There were two teaching software packages and four operational guides for the four teaching strategies

(1) IT-Integrated Teacher Demonstration Package (ITDP)

(2) IT-Integrated Guided Discovery Package (IGDP)

(3) Operational Guide for IT-Integrated Teacher Demonstration (OGITD)

(4) Operational Guide for IT-Integrated Guided Discovery (OGIGD)

(5) Operational Guide for Guided Discovery Strategy (OGGD)

(6) Operational Guide for Teacher Demonstration Strategy (OGTD)

3.6.1 Procedure for Development of IT-Integrated Teaching Packages

The Information Technology-integrated Teaching Packages (ITD and IGD) developed were based on the four topics; mole concept, rates of chemical reactions, oxidation and reduction reactions and electrolysis from the Senior Secondary School Chemistry Curriculum. The design of the IT-Integrated Teaching Packages adopted six stages of the ASSURE Model of Instructional System Design created by Henich, Molenda and Russel (1999) and used by Dick, Carey and Carey (2005). The IT-integrated Packages developed serve as alternative ways of organising the specified contents into teaching and learning units (activities). In other words, the interactive property of the packages, coupled with the simulations in it provided learning experiences that enhance the variables considered in this study.

3.6.2 The ASSURE Model (Henich, Molenda & Russel, 1999)

This model focussed specifically on planning and conducting instructions that incorporates media in educational process. Its main perspective was how to integrate any kind of media into instruction in a proper and effective way in terms of intended learning outcomes. This framework was adopted because it has become a framework frequently used in publications and discussions on introducing new technology in the teaching and learning processes. Faryardi, (2012; Al Musawi (2011); KENPRO (2010); Heinich & Smaldino (2002) regarded it as the most appropriate for implementing instruction with the aid of technology media.

ASSURE is an acronym of the six instructional designs and stands for:

- Analysing the learners:

In this study, the students sampled were analyzed based on their age, prior knowledge and they have also studied Chemistry for at least one year.

- Stating the objectives:

Here, the objectives are set. The objectives of the topics in the NERDC Chemistry curriculum served as the baseline for the model objectives for each of the topics in the study.

- Selection of the appropriate methods, media and materials:

Here, the contents are delivered using text, graphics, animations, simulations and relevant media.

- Utilisation of methods, media and materials: this is the interactions of relevant methods, media and materials selected to achieve the set objectives.

- Require Learners participation

In this study, the student participates by selecting the activities of each unit from the topics. The student performs the task that follow before moving to the next or return to the previous.

- Evaluation and revision:

Every unit of the model evaluates the learner. The packages provided for marking and corrections. And so, it is a continuing task/activity that follows the whole process and gives it a cyclic structure.

The content of each courseware package was divided into topics.

When developing the software teaching packages for the study, the researcher took into consideration the students' needs, the instructional objectives as well as the interface design.

The contents of the selected difficult topics/concepts in the Nigerian senior secondary school chemistry were written out by the researcher. It served as the content of the topics to be taught called Instructional Treatment Manual (ITM). Copies of the ITM were made and given to three experienced secondary school chemistry teachers and three chemistry lecturers in the Science and Technology Education Department and Chemistry department of the University of Lagos, Nigeria for thorough scrutiny. This was to ensure that it adequately covers the topics, and that there is no misrepresentation of scientific facts. The ITM was then transformed into an interactive teaching package suitable for classroom instruction.

Interface Design: the following important steps were taking into consideration to get the desired result in the development of the software:-

(i) windows/buttons/colours/font type;

(ii) the interface to be user-friendly;

(iii) the sequence of the screen to be logical;

(iv) allowing users to browse without getting lost and always know where they are;

(v) the program to be easy to use ; and

(vi) the feedback mechanism to ascertain the level of knowledge acquired

The IT-integrated packages (ITD and IGD) were produced in a Hypertext Markup Language (html) format using Macromedia Dreamweaver 8 as the overall platform. Other computer programmes that were also utilized during the development processes include CorelDraw graphics suit 12, Microsoft Word 2007, Macromedia Fireworks 8 and Macromedia Flash 8. CorelDraw and Microsoft Word were used for texts and graphics, Macromedia Fireworks was used for specific texts and graphics, and for buttons while Macromedia Flash 8 was used for the simulations. All these were carried out with the assistance of computer experts in programming and creation of animation as well as the secondary school chemistry teachers who would use the packages in the classrooms. The researcher with the help of the chemistry teacher provided specific layout instructions to the computer experts on how each item in the ITM was to be presented in the package.

Screenshots of the application

Brief snapshots of the module in the IGD and ITD used for intervention by the experimental groups during the study were shown under appendix X.

Login Module:

This is the module where the user is given access into the system once the application has been invoked. It requires no username .This can be seen in screenshot 1a- 1c (see appendix X).

Selected Learning Activity Module:

This is where the user clicks the activity to learn as guided by the teacher. These modules cover the learning/studying of the activity by the user. One activity differs from the other. There are several learning-activities under this module developed from each of the topics selected from Senior Secondary School Chemistry Curriculum of the NERDC. Screen shots 2a – 2g show some learning activities from each topic (see appendix IX).

Test and Correction Modules:

This module tests the knowledge acquired by the user after going through a particular activity. This is shown in screenshots 3a, b and c (see appendix IX). The user views the answers to the questions and has the opportunity to go back and answers the questions again or proceeds to the next activity module.

The activities of the IGD and ITD were based on the topics specified under Chemistry curriculum developed by NERDC. Devising a new interactive multimedia approach to Chemistry teaching permits alternative ways of organising the specified content into the teaching and learning units (modules and activities). This depict that a new curriculum is not being proposed, but a set of techniques for mediating and increasing learning experiences in Chemistry is being promoted.

3.6.3 Operational Guide for IT-Integrated Teacher Demonstration (OGITD)

This operational guide is teacher-centred and was used by the teachers in engaging students in the group (Experimental 1). It is an interactive teaching package with hands on activities and experiments. Teachers in this group use this to demonstrate while, the students watch closely and listen to teachers' explanation. The teachers were trained to use this guide and to pay close attention to the role of the students at each step of the presentation. The students are to discuss the procedures, knowledge, findings in the demonstrated activities within their class members and individual reports based on the demonstrated activities.

The procedural steps that are involved are:

Step 1: Teacher introduces the lesson/topic and encourages the students to pay attention and watch carefully the activity demonstrated with the ITD.

Step 2: Teacher uses the ITD to demonstrate the activities in the operational guide to the students.

Step 3: Students watch the demonstration and are allowed to ask any question on the activities demonstrated on the ITD.

Step 4: Students draw out the conclusion from the activities demonstrated on the ITD with feedback

Step 5: Students discuss the procedures, knowledge, theories and findings involved in the teachers demonstration activities and record in the notes.

(Appendix V- VIII). for example:

Rates of Reaction

(i) Marble chips with dilute acid (vigorous at the beginning but slow rate of reaction later)

(ii) Marble powder and dilute acid (showing vigorous and faster rate of reaction until completion of the reaction)

(iii) Silver trioxonitrate(V) and hydrochloric acid (white fume immediately the two come in contact)

(iv) Rusting of nail in air

3.6.4 Operational Guide for IT-Integrated Guided Discovery Package (OGIGD)

This operational guide is student-centred and was used by the teachers in engaging students taught in this group (Experimental 2). The teacher's role is to lead the students through a predetermined sequence of questions, activities and problems that have been programmed into the interactive software. Interactive animation and simulation are integrated into the guided discovery strategy. It involves the following procedural steps:

Step 1: The OGIGD provides illustrative materials by simulation for students to study on their own.

Step 2: Students identify and interact with the materials.

Step 3: Leading questions are then asked to enable students think and provide conclusion through the adoption of the processes of science.

Step 4: Students respond to these questions and get instant feedback that allow them to progress in constructing their own knowledge.

Step 5: Students discuss the findings, answer the questions and record in their notebooks (See appendix V-VIII).

3.6.5 Operational Guide for Guided Discovery Strategy (OGGD)

This operational guide is student-centred and was used by the teacher in engaging students in control group 1. The teacher's role is to lead the students through a predetermined sequence of questions, activities and problems, subject to feedback from the students. The steps to be followed are:

Step 1: The teacher provides illustrative materials (activities) for students to study and interact with on their own.

Step 2: Leading questions are then asked by the teacher to enable students think and provide answers through the adoption of the processes of science.

Step 3: The teacher guides the students and helps them by acting as a facilitator taking them through the activities on each topic to arrive at knowledge construction on their own

Step 4: Students discuss the findings, answer the questions and record in their notebooks. (See appendix V-VIII).

3.6.6 Operational Guide for Teacher Demonstration (OGTD)

This instructional guide consists of activities to reflect those concepts that were in OGITD, OGIGD and GD. The main feature of the guide was teacher-centred. It followed the same pattern as the ITD but lack the demonstration by the use of interactive animations and simulations. Instead, real experiments are demonstrated for students to observe.

The procedural steps that are involved are:

Step 1: Teacher introduces the lesson/topic and encourages the students to pay attention and watch carefully the activity demonstrated with real hand on activity.

Step 2: Teacher demonstrate the activities in the operational guide to the students.

Step 3: Students watch the demonstration and are allowed to ask any question on the activities demonstrated.

Step 4: Students draw out the conclusion from the activities demonstrated on the ITD with feedback

Step 5: Students discuss the procedures, knowledge, theories and findings involved in the teachers demonstration activities and record in the notes (See appendix V-VIII).

3.7 Validity and Reliability of the Research Instruments

The CCUT and PSST were individually face validated to determine the appropriateness and relevance of the instruments to the research topic by the researcher's supervisors and two other experts in the Department of Science and Technology Education, Faculty of Education, University of Lagos, Akoka, Lagos State. The two instruments were reconstructed based on their comments.

Content validity of the instruments was carried out using 2 secondary school Chemistry teachers who verified the relevance, appropriateness and adequate coverage of the topics and made their input. The modified instruments were test –retested a week after the first administration on 32 chemistry students who were not part of the sample for the study. The reliability of each of CCUT and PSST were determined using Pearson Moment Correlation Formula. The reliability values of 0.73 and 0.81 were obtained for CUT and PSST respectively.

Science Process Skills Test (SPST) developed by the researcher was given to two science educators to determine its construct, content and face validation. The instrument was modified based on their comments. The modified instrument was administered to 32 chemistry students who were not part of the sample for the study. The discriminating indices of each of the items and difficulty levels were computed. The items with moderate difficulty indices of 0.4 to 0.6 were retained to ensure that such item had positive correlation with entire test. The responses of the students were used to determine the reliability using Kuder-Richardson formula 20 (KR-20) with reliability value of 0.83.

The 21st century skills test was face, contentment and construct validated by two science educators. The instrument was test-retested on 32 chemistry students a week after the first administration and the scores were correlated using Spearman rank correlation method. The reliability value obtained was 0.81.

3.7.1 Validity and Reliability of the Treatment Packages

Validation of the treatment packages was carried out using a Subject Content Validation Questionnaire administered to five chemistry teachers from two secondary schools which were not part of the sampled schools. The results showed that the teachers strongly agreed with every statement in the questionnaire which includes adequate coverage of the topics content in the official secondary school chemistry curriculum. The fact that all the teachers strongly agreed to this statement indicated that the subject matter content adequately and sufficiently covered the topics selected from the Nigerian secondary school chemistry curriculum.

The IT-Integrated teaching packages were validated by two computer experts who checked the packages for legibility, clarity of the typing, movement of the cursor in particular direction desired (navigation), functionality of the simulations and animations, packaging and durability. Both computer experts were agreed that the legibility and navigation of the content of the packages were in order. One of them recommended that some of the font sizes should be increased. Also, they both agreed that the packages were user friendly. They both claimed that the simulations were appropriate as they conveyed the messages of the content and that the links worked well in terms of functionality.

3.7.2 Pilot Study

Pilot study was carried out to further determine the validities and reliabilities of the instruments and the treatment packages. This was carried out in five schools randomly selected from Lagos State Education Districts II and III but that were not part of the sampled schools for the main study. The five schools were randomly assigned to three treatment groups (ITD, IGD and GD). Chemistry students in their intact classes in the selected schools were the sample for the pilot study. The total sample for the pilot study was 133 chemistry students. The students in their intact classes were taught with the three teaching strategies (2 experimental and 1 control). The feedbacks from the pilot study were used to improve on the main study.

3.8 Research Procedure

The study commenced at the beginning of the second term of 2014/2015 academic session. The duration of the field work was twelve weeks. The procedure include; training of the Chemistry teachers, pre-test administration, treatments and post-test administration.

3.8.1 Training of the Chemistry Teachers: The researcher trained twelve (12) SS II chemistry teachers (6 teachers for ITD and 6 teachers for IGD) in the sampled schools on the use of the teaching packages to teach the selected topics for two weeks. Using the package, step by step operational guides on each of the topics in the two experimental teaching strategies were followed to train the teachers.

Teacher Training Format

Objectives: the objective of the training is to equip the teachers with necessary knowledge, skills and attitudes for engaging the students in the experimental groups.

Number of teachers trained: 6 for ITD and 6 for IGD

Training Duration: 2 weeks

Venue for the Training: 2 different secondary schools

The Intervention: the intervention was a multi-component training programme that included:

(a) The researcher discussed the teaching strategy with the teachers as it was applicable to each sampled schools.
   (i) The researcher vividly discussed the intricacies of the teaching strategies
   (ii) Preparation of the class for IT instruction
   (iii) Point out the different nodes in the teaching strategy in each of the topics
(b) The researcher used the operational guide to create a lesson while the teachers observed
(c) The teacher role-played the teaching strategy using the operational guide for the researcher and other teachers to observe

(d) The researcher and other teachers assessed the trained teachers' competency in the implementation of the lesson guide using rating scale for teachers' competency format (see appendix VIII).

The training took place 3 hours a day and 3 days per week. The role of the teacher and the point at which they come in were clearly specified step by step through the course of the training. Six teachers with higher competences were picked for the treatment groups (3 teachers each for ITD and IGD) at the 3rd week.

3.8.2 Pre-test Administration:

All the Chemistry students in their intact classes in the twelve (12) schools selected were pre-tested at the 4th week using the four instruments in the following order:

- CCUT: Chemistry Conceptual Understanding Test
- PSST: Problem-solving Skills Test
- SPST: Science Process Skills Test
- 21ST CST: 21st Century Skills Test

Pre-test was carried out to find out the initial differences between the groups. The test administration was conducted by the Chemistry teachers.

3.8.3 Treatments on experimental and control groups:

Chemistry teachers in the selected schools implemented the teaching strategies as assigned to each school. The four selected difficult topics were taught with both experimental (ITD and IGD) and control (TD and GD) strategies using the operational guides. The duration of the implementation of the teaching strategies for the study lasted six weeks. To ensure compliance, the researcher went round the schools to make sure the teachers were following the operational guide for each strategy.

3.8.4 Post-test Administration:

One week after the implementation of the strategies, all the students in their intact classes were tested using the same instruments as in the pre-test following the same order:

- CCUT: Chemistry Conceptual Understanding Test
- PSST: Problem-solving Skills Test
- SPST: Science Process Skills Test
- 21^{ST} CST: 21^{st} Century Skills Test

3.9 Method of Data Analysis

Data collected were analyzed using mean, standard deviation and Analysis of Co-variance (ANCOVA) where pre-test scores served as covariates so as to take care of the initial differences among the groups. Where there were significant differences, the direction of significant differences were further analyzed using the Bonferoni post-hoc test.

CHAPTER FOUR

PRESENTATION OF DATA AND INTERPRETATION OF RESULTS

This chapter presents the results of the study. The results are presented in line with the questions raised and the hypotheses formulated. The summary of the research findings are presented and discussions focused on the findings relative to the research questions answered and the hypotheses tested.

4.1 Answering the Research Questions and Testing the Hypotheses

Answers were provided to seven research questions and also, seven hypotheses were tested.

4.1.1 Research Question 1: What is the effect of the treatment (IT-integrated Teacher Demonstration, IT-integrated Guided Discovery, Guided Discovery and Teacher Demonstration teaching strategies) on chemistry students' learning outcomes?

The mean, mean difference and standard deviation of the treatment groups- IT-integrated Teacher Demonstration (ITD) strategy, IT-integrated Guided Discovery (IGD) strategy, Guided Discovery (GD) Strategy and Teacher Demonstration (TD) Strategy groups on each of the learning outcomes were used to answer the question as shown on Table 4.1.

Table 4.1: Descriptive Statistics of pre and post-treatment learning outcomes scores based on treatment

Treatment	Learning Outcomes	Mean (pre-test)	Std Dev	Mean (Post-test)	Std Dev	Mean Difference
IT-Integrated Teacher demonstration (ITD)	Conceptual Understanding	9.71	3.319	13.92	2.761	4.21
	Problem Solving	8.61	3.856	12.10	3.738	3.49
	Sci Process Skills	31.27	2.027	33.49	2.681	2.22
	21STCentury Skills	49.07	2.792	52.42	4.183	3.35
IT-Integrated Guided Discovery (IGD)	Conceptual Understanding	8.47	3.989	15.39	4.233	6.92
	Problem Solving	8.36	2.882	14.42	3.170	6.02
	Sci Process Skills	31.22	2.008	36.17	2.219	4.95
	21STCentury Skills	51.18	4.331	56.75	3.192	5.57
Guided Discovery (GD)	Conceptual Understanding	8.32	3.975	12.40	3.744	4.08
	Problem Solving	7.11	3.102	11.41	4.153	4.30
	Sci Process Skills	31.36	2.001	34.11	2.079	2.75
	21STCentury Skills	49.27	2.480	51.71	2.888	2.44
Teacher Demonstration	Conceptual Understanding	8.98	3.478	10.65	3.568	1 .67
(TD)	Problem Solving	8.72	3.888	11.94	3.974	3.22
	Sci Process Skills	31.27	1.981	33.23	2.327	1 .96
	21STCentury Skills	50.17	5.384	52.60	5.011	2.43

Table 4.1 shows the mean, standard deviation and mean difference of the four learning outcomes before and after the treatments. The higher the mean difference, the more effective the strategy.

The teaching strategy that was most effective for all the four learning outcomes was ICT-integrated Guided Discovery (IGD) based on the mean difference as shown on Table 4.1. The values are 6.92, 6.02, 4.95 and 5.57 for conceptual understanding, problem-solving, science process skills and 21st century skills acquisitions respectively. Each of the values was the highest among the four treatment groups. Further, conceptual understanding had the highest mean difference of 6.92 which means that IT-integrated guided discovery (IGD) is most effective in teaching for conceptual understanding.

Comparing the two (2) experimental groups- ITD and IGD, IGD group performed better than ITD group in the four learning outcomes. Also, the two experimental groups (ITD and IGD) performed better than their corresponding control groups (TD and GD) in the four learning outcomes.

Observations based on learning outcomes showed that: the mean difference of the conceptual understanding scores of students taught by ITD strategy (4.21) was slightly higher than those taught by GD strategy (4.08). In problem-solving, the mean difference of students taught by ITD strategy (3.49) was lower than those taught by GD strategy (4.30). For science process skills, GD strategy group (2.75) performed better than ITD demonstration strategy group (2.22). 21st century skills acquisition is the only learning outcome where ITD strategy (3.35) was seen to be more effective than GD strategy (2.44). Furthermore, TD strategy was the least effective of all the strategies on chemistry students' learning outcomes.

To test for the significance of the differences, the $H_0 1$ was tested.

Hypothesis $H_0$1: There is no significant main effect of treatment (IT-integrated Teacher Demonstration, IT-integrated Guided Discovery, Guided Discovery and Teacher Demonstration teaching strategies) on students' learning outcomes in chemistry.

The hypothesis was tested on each of the learning outcomes.

(i) Conceptual Understanding

To determine if the differences in post-test and pre-test scores of conceptual understanding are significant across the four groups, ANCOVA technique was employed. Post-test scores on conceptual understanding were entered as the dependent variable; experimental condition was entered as the independent factor, while the pre-test scores in conceptual understanding were entered as the covariates as presented on Table 4.2.

Table 4.2: Summary of Analysis of Covariance of treatment on conceptual understanding among chemistry students.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5808.719[a]	4	363.045	187.088	.000	.875
Intercept	1812.807	1	1812.807	934.194	.000	.685
PRECUT (Covariates)	4135.260	1	4135.260	2131.024	.000	.832
TREATMENT	832.364	3	277.455	142.981	.000*	.500
Error	832.476	441	1.941			
Total	80489.000	446				
Corrected Total	6641.195	445				

a. R Squared = .875 (Adjusted R Squared = .870)
b. * significant at 0.05
c. PRECUT = Pretest Conceptual Understanding

Table 4.2 shows that for treatment condition, the calculated F-value of 142.981 was significant at $p<0.05$ given degrees of freedom 3 and 441 ($F_{3, 441} = 142.981$, $p = 0.000$). This means that there was a significant effect of treatment on conceptual understanding among chemistry students. Hence, the null hypothesis H_O1 is rejected for conceptual understanding. The partial eta squared value of .500 showed that treatment had 50% contributory effect to the significance.

Based on the significant F-value obtained from Table 4.2, further analysis of data was done using the Bonferoni Post Hoc Pairwise comparison analysis to determine which group differs from the other and the trend of the difference. The result of the post hoc analysis is shown in Table 4.3

Table 4.3: Bonferoni Post Hoc Pairwise comparison on experimental and control groups

(I) TREATMENT	(J) TREATMENT	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	und
IT-integrated Teacher Demonstration (ITD)	IT-integrated Guided Discovery (IGD)	-3.096*	.296	.000*	-3.678	-2.513
	Guided Discovery (GD)	.309	.239	.197	-.161	.778
	Teacher Demonstration (TD)	2.456*	.235	.000*	1.994	2.917

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferoni.

The result indicated that ITD strategy was significantly different from IGD strategy (0.000) and TD strategy groups (0.000) But, there was no significant difference between ITD strategy group and GD strategy group (0.197). Furthermore, IGD strategy group differed significantly from ITD strategy group, GD strategy and TD strategy groups. Thus, the null hypothesis is rejected for conceptual understanding. Hence, there is a significant effect of the treatment on conceptual understanding of students in chemistry.

(ii) Problem solving Skills

Problem solving skills is another dependent variable in this study. To determine the significant effect of the treatment on problem solving skills across the four groups, ANCOVA technique was employed. Post-test scores on problem solving skills were entered as the dependent variable; experimental condition was entered as the independent factor, while the pre-test scores in problem solving skills were entered as the covariates. The results are shown in Table 4.4.

Table 4.4: Summary of Analysis of Covariance of treatment on problem solving skills among chemistry students

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5808.719[a]	4	363.045	187.088	.000	.875
Intercept	1812.807	1	1812.807	934.194	.000	.685
PREPSST (Covariates)	5121.210	1	5121.210	5150.914	.000	.923
TREATMENT	564.290	3	188.097	189.188	.000*	.570
Error	832.476	441	1.941			
Total	80489.000	446				
Corrected Total	6641.195	445				

a. R Squared = .944 (Adjusted R Squared = .942) b. *significant at < 0.05 c. PREPSST = pretest problem solving skills test

Table 4.4 shows that for treatment condition, the calculated F-value of 189.188 is significant at p< 0.05 given 3 and 441 degrees of freedom ($F_{(3, 441)}$ = 189.188, p = 0.000). Hence, the null hypothesis is rejected. This means that there is significant effect of the treatment on problem solving skills among chemistry students. The partial eta squared of 0.570 accounts for 57% contribution of treatment to the effect. In other words, there is a significant difference in the post tests scores of students' problem-solving skills in the four groups after treatment.

Based on the significant F-value obtained from Table 4.4, further analysis of data was done using the Bonferroni Post Hoc Pairwise comparison to determine source and the trend of the significant difference. The result of the post hoc analysis is shown in Table 4.5.

Table 4.5: Bonferroni Post Hoc Pairwise comparison on experimental and control groups

(I) TREATMENT	(J) TREATMENT	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
IT-integrated Teacher Demonstration(ITD)	IT-integrated Guided Discovery (IGD)	-2.918*	.151	.000*	-3.215	-2.621
	Guided Discovery (GD)	-.519*	.121	.000*	-.756	-.281
	Teacher Demonstration (TD)	2.018*	.120	.000*	1.783	2.253

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons:Bonferoni.

From Table 4.5, the result indicated a significant difference between ITD strategy group and IGD strategy group (0.000). Also, ITD strategy group was significantly different from GD and TD strategies groups (0.000). IGD was significantly different from GD (0.000) and TD (0.000). GD also differed significantly from TD strategy group (0.000) on students' problem-solving skills acquisition in chemistry. Thus, the null hypothesis is rejected. Hence, there is a significant effect of treatment on chemistry students' problem-solving skills.

(iii) Science Process Skills

Science process skills acquisition is another dependent variable in this study. To determine significant effect of treatment on science process skills acquisition across the four groups, ANCOVA technique was employed. Post-test scores on science process skills were entered as the dependent variable; experimental condition was entered as the independent factor, while the pre-test scores in acquisition of science process skills were entered as the covariates. The results are shown in Table 4.6.

Table 4.6: Summary of Analysis of Covariance of Treatment on Acquisition of Science Process among chemistry students

Corrected Model	5808.719[a]	4	363.045	187.088	.000	.875
Intercept	1812.807	1	1812.807	934.194	.000	.685
PRESPST	1716.997	1	1716.997	3372.157	.000	.887
TREATMENT	694.820	3	231.607	454.872	.000*	.761
Error	832.476	441	1.941			
Total	80489.000	446				
Corrected Total	6641.195	445				

a. R Squared = .932 (Adjusted R Squared = .929) b.* significant at 0.05 c. PRESPST = pretest science process skills test

Table 4.6 shows that for the treatment condition, the calculated F-value of 454.872 was significant at p<.05 given 3 and 429 degrees of freedom, (F $_{(3, 441)}$) = 454.872, p = 0.000). The partial eta squared of .761 accounts for 76% contribution of the treatment condition. This means that there is a significant effect of treatment on science process skills acquisition among chemistry students.

Based on the significant F-value obtained, further analysis of data was done using the Bonferoni Post Hoc Pairwise comparison analysis to determine which group differs from the other and the trend of the difference. The result of the post hoc analysis is shown in Table 4.7.

Table 4.7: Bonferoni Post Hoc Pairwise comparison on experimental and control groups

(I) TREATMENT	(J) TREATMENT	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
IT-integrated Teacher Demonstration (ITD)	IT-integrated Guided Discovery (IGD)	-2.570*	.211	.000	-2.984	-2.156
	Guided Discovery (GD)	.230	.169	.173	-.102	.562
	Teacher Demonstration (TD)	2.082*	.170	.000	1.747	2.417

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisonsBonferoni).

From table 4.7, ITD strategy group differed significantly from IGD (0.000) and TD strategy group (0.000). But, there is no significant difference between ITD strategy group and GD strategy group (0.173). Furthermore, IGD strategy group differed significantly from ITD strategy group, GD strategy group and TD strategy group. TD group was significantly different from ITD strategy group, IGD strategy group and GD strategy group. Thus, the null hypothesis is rejected. It is concluded that there is a significant main effect of treatment on chemistry students' acquisition of science process skills.

(iv) 21st Century Skills

To determine if there is a significant effect of treatment on acquisition of 21st century skills across the four groups, ANCOVA technique was employed. Post-test scores on 21st Century Skills were entered as the dependent variable; experimental condition was entered as the independent factor, while the pre-test scores in acquisition of 21st century skills were entered as the covariates. The results are shown in Table 4.8.

Table 4.8: Summary of Analysis of Covariance of Treatment on Acquisition of 21st century skills among chemistry students

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5808.719[a]	4	363.045	187.088	.000	.875
Intercept	1812.807	1	1812.807	934.194	.000	.685
PRE21STCST	2161.934	1	2161.934	987.053	.000	.697
TREATMENT	334.671	3	111.557	50.933	.000*	.263
Error	832.476	441	1.941			
Total	80489.000	446				
Corrected Total	6641.195	445				

a. R Squared = .879 (Adjusted R Squared = .875) b.* significant at 0.05 c. PRE21STCST = pretest 21st century skills test

Table 4.8 shows that for treatment condition, the calculated F-value of 50.9333 is significant $p < 0.05$ given 3 and 441 degrees of freedom ($F_{(3, 441)} = 50.9333$, $p < 0.000$). This means that there is significant effect of treatment on 21st century skills acquisition among chemistry students. The null hypothesis is therefore rejected.

Based on the significant F-value obtained, further analysis of data was done using the Bonferoni Post Hoc Pairwise comparison analysis to determine which group differs from the other and the trend of the difference. The result of the post hoc analysis is shown in Table 4.9.

Table 4.9: Bonferoni Post Hoc Pairwise comparison on experimental and control groups

(I) TREATMENT	(J) TREATMENT	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
IT-Integrated TEACHER DEMONSTRATION (ITD)	IT-Integrated GUIDED DISCOVERY (IGD)	-2.642*	.313	.000	-3.257	-2.026
	GUIDED DISCOVERY (GD)	.112	.286	.695	-.450	.674
	TEACHER DEMONSTRATION (TD)	1.396*	.288	.000	.830	1.962

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferoni (equivalent to no adjustments).

The result indicated a significant difference between ITD strategy group and IGD strategy group. Also, there is a significant difference between ITD strategy group and TD strategy group. But, there is no significant difference between ITD strategy group and GD strategy group. There are significant differences between IGD strategy group and ITD strategy group and between IGD strategy group, GD and TD strategy groups. TD strategy group is significantly different from the ITD strategy group, IGD group and GD strategy group. Thus, the null hypothesis is rejected. It is concluded that there is a significant main effect of treatment on chemistry students' 21st century skills.

The null hypothesis is rejected for all the four learning outcomes. It can therefore be inferred that there is a significant effect of treatment on all the four chemistry learning outcomes.

4.1.2 Research Question 2: What is the effect of school type on chemistry students' learning outcomes?

The mean, mean difference and standard deviation of public and private school chemistry students on each of the learning outcomes as shown on table 4.10 were used to answer the question.

Table 4.10: Descriptive Statistics of pre and post-treatment learning outcomes scores based on school type

School Type	Learning Outcomes	Mean Scores (pre-test)	Std Dev (SD)	Mean Scores (Post-test)	Std Dev (SD)	Mean Difference
Public	Conceptual Understanding	8.7983	3.72415	12.8992	3.87602	4.1009
	Problem solving Skills	8.1345	3.52182	11.4370	4.05919	3.3025
	Science Process Skills	31.3361	1.97574	33.5378	2.70701	2.2017
	21stCentury Skills	49.0700	2.64854	51.8852	3.25088	2.8152
Private	Conceptual Understanding	9.1573	3.66463	12.7416	3.83029	3.5843
	Problem solving Skills	8.1461	3.61986	11.3146	4.53420	3.1685
	Science Process Skills	31.0787	2.10100	33.2921	2.58141	2.2134
	21stCentury Skills	52.5843	6.03552	54.5618	6.31728	1.9775

Results indicated that the mean differences of public school students were higher than those of their counterparts in private school in conceptual understanding, problem-solving skills and 21st century skills. It is only science process skills that the mean difference of students in private schools is slightly higher than that of their counterparts in public schools (Table 4.10). This means that school type had positive effect on chemistry students in all the four chemistry learning outcomes considered.

Null hypothesis 2 was tested to ascertain the significant effect of school type on chemistry students' learning outcomes.

Hypothesis Ho2 : There is no significant main effect of school type on students' learning outcomes in chemistry.

(i) Conceptual Understanding

The summary of ANCOVA on Table 4.11 shows the significance value of school type on conceptual understanding.

Table 4.11: Summary of Analysis of Covariance of School Type on conceptual understanding among chemistry students.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5808.719[a]	2	363.045	187.088	.000	.875
Intercept	1812.807	1	1812.807	934.194	.000	.685
PRECUT (Covariates)	4135.260	1	4135.260	2131.024	.000	.832
SCHLTYPE	9.115	1	9.115	4.697	.031*	.011
Error	832.476	443	1.941			
Total	80489.000	446				
Corrected Total	6641.195	445				

d. R Squared = .875 (Adjusted R Squared = .870)
e. * significant at 0.05
f. PRECUT = pretest conceptual understanding test

Table 4.11 showed that for school type, the calculated F-value of 4.697 was significant at $p < 0.05$ given degrees of freedom 1 and 443 ($F_{1, 443} = 4.697$, $p = 0.031$. This means that there is a significant effect of school type on conceptual understanding among chemistry students.

The partial eta squared value of .011 showed that school type had just 1% contributory effect to the significance. Therefore, the null hypothesis was rejected for conceptual understanding.

(ii) Problem solving Skills

The summary of ANCOVA on Table 4.12 shows the significance value of school type on Problem solving Skills.

Table 4.12: Summary of Analysis of Covariance of School Type on problem solving skills among chemistry students

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5808.719[a]	2	363.045	187.088	.000	.875
Intercept	1812.807	1	1812.807	934.194	.000	.685
PREPSST (Covariates)	5121.210	1	5121.210	5150.914	.000	.923
SCHLTYPE	.099	1	.099	.099	.753	.000
Error	832.476	443	1.941			
Total	80489.000	446				
Corrected Total	6641.195	445				

a. R Squared = .944 (Adjusted R Squared = .942) b. *significant at < 0.05

Table 4.12 showed that p= 0.753 at p<0.05 given degrees of freedom 1 and 443 ($F_{1,\ 443}$ = .099) which is not significant. The partial eta squared value is 0.000 which means that school type did not contribute to the effect on chemistry students' problem-solving skills. Thus, the null hypothesis was accepted for problem-solving. There is no significant effect of school type on problem-solving skills among chemistry students.

(iii) Science Process Skills

The summary of ANCOVA on Table 4.13 shows the significance value of school type on Science Process Skills.

Table 4.13: Summary of Analysis of Covariance of School Type on Science Process Skills Acquisition among chemistry students

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5808.719[a]	2	363.045	187.088	.000	.875
Intercept	1812.807	1	1812.807	934.194	.000	.685
Pretest Science Process Skills	1716.997	1	1716.997	3372.157	.000	.887
SCHLTYPE	3.589	1	3.589	7.049	.008*	.016
Error	832.476	443	1.941			
Total	80489.000	446				
Corrected Total	6641.195	445				

a. R Squared = .944 (Adjusted R Squared = .942) b. *significant at < 0.05

Table 4.13 showed that p = 0.008 which is significant at $p< 0.05$ given degrees of freedom 1and 443 ($F_{1,443} = 7.049$). There is a significant effect of school type on chemistry students' acquisition of science process skills. Therefore the null hypothesis is rejected for science process skills.

(iv) 21st Century Skills

The summary of ANCOVA on Table 4.14 shows the significance value of school type on 21st Century Skills.

Table 4.14: Summary of Analysis of Covariance of School Type on 21st Century Skills Acquisition among chemistry students

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5808.719[a]	2	363.045	187.088	.000	.875
Intercept	1812.807	1	1812.807	934.194	.000	.685
PRE21STCST	2161.934	1	2161.934	987.053	.000	.697
SCHLTYPE	6.797	1	6.797	3.103	.079	.007
Error	832.476	443	1.941			
Total	80489.000	446				
Corrected Total	6641.195	445				

a) R Squared = .879 (Adjusted R Squared = .875) (b) P= 0.05 (c) pre21stCST = pre 21st century skills test

Table 4.14 shows that p= 0.079 which is not significant at $p < 0.05$ given degrees of freedom 1 and 443 ($F_{1, 443} = 3.103$). Thus, the null hypothesis was accepted for 21st century skills. In summary, the null hypothesis is rejected for conceptual understanding and science process skills acquisition and accepted for problem solving skills and 21st century skills acquisition.

4.1.3 Research Question 3: What is the influence of gender on students' learning outcomes in chemistry?

To answer the research question, Table 4.15 shows the mean differences of students on the four learning outcomes by gender.

Table 4.15: Results of statistical analysis of pre and post-treatment learning outcomes scores based on gender

Gender	Learning Outcomes	Mean Scores (pre-test)	Std Dev (SD)	Mean Scores (Post-test)	Std Dev SD	Mean Difference
Male	Conceptual Understanding	8.7197	3.65283	13.0833	3.79722	4.3636
	Problem solving Skills	8.2121	3.38309	11.7538	4.02038	3.5417
	Science Process Skills	31.2159	2.00635	33.6742	2.78097	2.4583
	21stCentury Skills	49.8598	3.74359	52.7803	4.18274	2.9205
Female	Conceptual Understanding	9.0879	3.79342	12.5549	3.94643	3.467
	Problem solving Skills	8.0275	3.75703	10.9176	4.30197	2.8901
	Science Process Skills	31.3846	1.99596	33.2198	2.51318	1.8352
	21stCentury Skills	49.6429	3.99709	51.8956	4.13783	2.2527

The mean differences of male students are generally higher in the four learning outcomes than those of their female counterparts as shown on Table 4.15.

To ascertain the significant effect of gender null hypothesis 3 was tested.

Hypothesis Ho3: There is no significant influence of gender on students' learning outcomes in chemistry.

(i) Conceptual Understanding

Table 4.16 showed the test of significance for conceptual understanding

Table 4.16: Summary of Analysis of Covariance of influence of Gender on conceptual understanding among chemistry students.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5808.719[a]	2	363.045	187.088	.000	.875
Intercept	1812.807	1	1812.807	934.194	.000	.685
PRECUT (Covariates)	4135.260	1	4135.260	2131.024	.000	.832
Gender	.664	1	.664	.342	.559	.001
Error	832.476	443	1.941			
Total	80489.000	446				

(a) R Squared = .875 (Adjusted R Squared = .870) (b) * significant at 0.05 (c) PRECUT = pretest conceptual understanding

The results of summary of ANCOVA on Table 4.16 showed the significant value for conceptual understanding to be $p = 0.0559$, which is not significant at $p < 0.05$. Therefore, the null hypothesis is accepted. Gender does not have significant influence on chemistry students' conceptual understanding.

(ii) Problem solving Skills

Table 4.17 shows the test of hypothesis for problem solving skills

Table 4.17: Summary of Analysis of Covariance of Gender on problem solving skills among chemistry students

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5808.719[a]	2	363.045	187.088	.000	.875
Intercept	1812.807	1	1812.807	934.194	.000	.685
PREPSST (Covariates)	5121.210	1	5121.210	5150.914	.000	.923
Gender	.332	1	.332	.334	.563	.001
Error	832.476	443	1.941			
Total	80489.000	446				

a. R Squared = .944 (Adjusted R Squared = .942) b. $p < 0.05$ c. PREPSST = pretest problem solving skills test

Table 4.17 for problem-solving showed p =0.0563, which is not significant at $p< 0.05$. Therefore, the null hypothesis is accepted. Gender does not have significant influence on chemistry students' problem-solving skills.

(iii) Science process skills

Table 4.18 shows the test of hypothesis for Science Process Skills

Table 4.18: Summary of Analysis of Covariance of Gender on Science Process Skills Acquisition among chemistry students

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5808.719[a]	2	363.045	187.088	.000	.875
Intercept	1812.807	1	1812.807	934.194	.000	.685
Pre test Science Process Skills Test	1716.997	1	1716.997	3372.157	.000	.887
Gender	.092	1	.092	.180	.671	.000
Error	832.476	443	1.941			
Total	80489.000	446				
Corrected Total	6641.195	445				

Table 4.18 for science process skills showed p= 0.671 which is not significant at $p< 0.05$. Therefore, the null hypothesis is accepted. Gender does not have significant influence on chemistry students' science process skills.

(iv) 21st century Skills

To test for the hypothesis on 21st century skills

Table 4.19: Summary of Analysis of Covariance of Gender on 21st Century Skills Acquisition among chemistry students

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5808.719[a]	2	363.045	187.088	.000	.875
Intercept	1812.807	1	1812.807	934.194	.000	.685
PRE21STCST	2161.934	1	2161.934	987.053	.000	.697
Gender	.445	1	.445	.203	.653	.000
Error	832.476	443	1.941			
Total	80489.000	446				
Corrected Total	6641.195	445				

(a) R Squared = .879 (Adjusted R Squared = .875) (b) $P < 0.05$ (c) pretest 21st century skills test

Table 4.19 for 21st century skills showed that p = 0.0653 which is not significant at $p < 0.05$. Therefore, the null hypothesis is accepted. Gender does not have significant influence on chemistry students' acquisition of 21st century skills.

There was no significant influence of gender on all the four chemistry learning outcomes. Therefore, the null hypothesis is accepted for all the four chemistry learning outcomes.

4.1.4 Research Question 4: What is the interaction effect of treatment and school type on chemistry students' learning outcomes?

The mean, mean difference and standard deviation of public and private school chemistry students on each of the learning outcomes taught with different strategies as shown on Table 4.20 to table 4.23 were used to answer the question for each of the four learning outcomes.

Table 4.20: Results of statistical analysis of pre and post-treatment conceptual understanding scores based on treatment and school type

Treatment	Learning Outcomes	School Type	Mean Scores (pre-test)	Std Dev (SD)	Mean Scores (Post-test)	Std Dev (SD)	Mean Difference
ITD	Conceptual Understanding	PUBLIC	9.3882	3.32055	13.7294	2.74897	4.3412
		PRIVATE	11.2222	2.94170	14.8333	2.70620	3.6111
IGD		PUBLIC	8.4429	4.03476	15.9857	3.02402	7.5428
		PRIVATE	8.6154	3.88455	15.3846	4.23357	6.7692
GD		PUBLIC	8.4375	4.02051	12.5625	3.80253	4.125
		PRIVATE	7.9286	3.85793	11.8571	3.54562	3.9285
TD		PUBLIC	8.7983	3.72415	12.8992	3.87602	4.1009
		PRIVATE	9.1573	3.66463	12.7416	3.83029	3.5842

The interaction effect of treatment and school type on conceptual understanding is shown on Table 4.20. The mean differences of students in public schools are higher than those of their counterparts in private schools in all the four treatment groups. Further, IGD strategy (7.5428) had the greatest effect on public school students followed by ITD (4.3412). GD strategy followed closely with 4.125. TD has the least effect on public schools (3.5842). The same trend was followed by private school.

Null Hypothesis 4 tests for the significant Interaction effect of treatment and school type on students' learning outcomes.

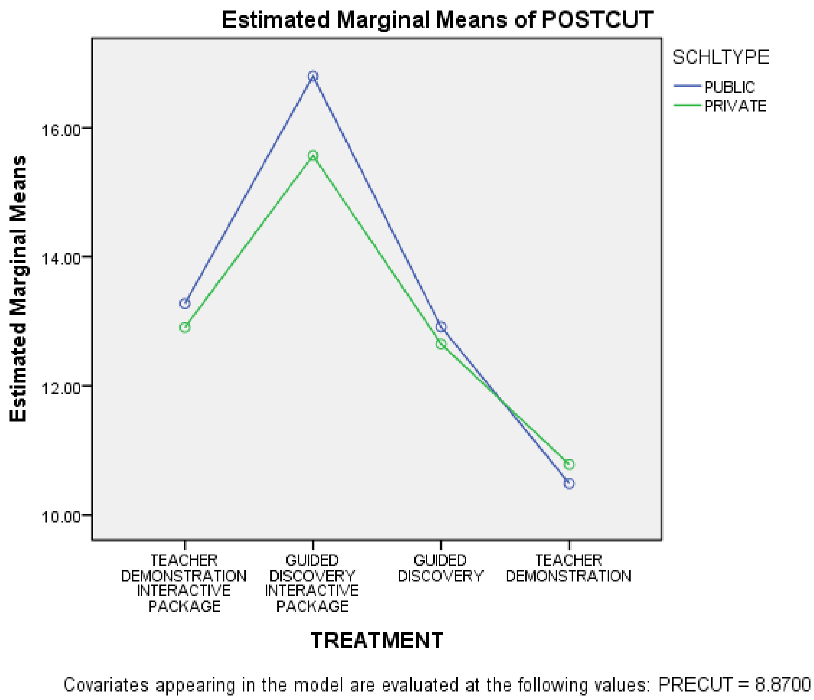


Figure 4.1: Interaction Effect of Treatment and School Type on Conceptual Understanding

Table 4.21: Interaction Effect of Treatment and School Type on Problem-solving Skills

Treatment	Learning Outcomes	School Type	Mean (x) Scores pre-test (x)	Std Dev SD	Mean (x) Scores Post-test (x)	Std Dev SD	Mean Difference
ITD	Problem solving Skills	PUBLIC	8.4235	3.85875	11.8824	3.79352	3.4589
		PRIVATE	9.5000	3.82330	13.1111	3.37620	3.6111
IGD		PUBLIC	8.1429	2.95515	14.2000	3.28192	6.0571
		PRIVATE	9.5385	2.18386	15.6154	2.21880	6.0769
GD		PUBLIC	8.1345	3.52182	11.4370	4.05919	3.3025
		PRIVATE	8.8929	3.89053	12.2857	4.33638	3.3928
TD		PUBLIC	8.6667	3.90591	11.8438	3.88066	3.1771
		PRIVATE	8.1461	3.61986	11.3146	4.53420	3.1685

Table 4.21 shows the interaction effect of treatment and school type on problem-solving skills. The mean differences of private school students are higher than their counterparts in

public schools in all the treatments except TD. IGD strategy had the greatest effect on both private and public schools followed by ITD strategy in both schools. For both public and private schools, the effectiveness of the treatments follows the same pattern for problem-solving. The most effective was IGD strategy followed by ITD strategy followed by GD strategy. The least effective strategy was TD strategy.

Table 4.22 below showed the interaction effect of treatment and school type on acquisition of science process skills.

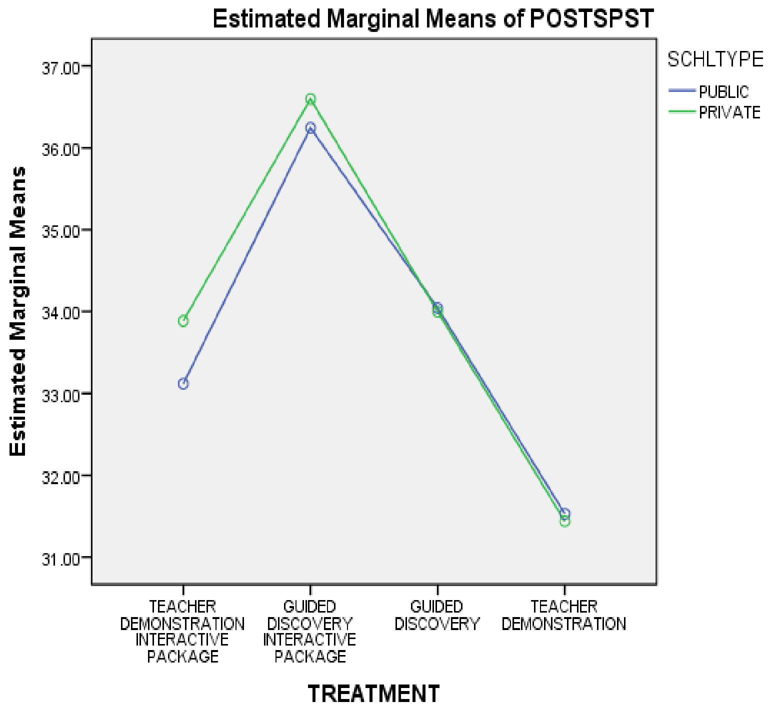
Table 4.22 Interaction Effect of Treatment and School Type on Science process Skills

Treatment	Learning Outcomes	School Type	Mean (x) Scores pre-test (x)	Std Dev SD	Mean (x) Scores Post-test (x)	Std Dev SD	Mean Difference
ITD	Science Process Skills	PUBLIC	31.2358	1.96421	33.5378	2.70701	2.302
		PRIVATE	31.2778	1.93438	33.8889	1.99673	2.6111
IGD		PUBLIC	31.3429	2.02080	36.2000	2.24964	4.8571
		PRIVATE	30.6154	1.89466	36.0000	2.12132	5.3846
GD		PUBLIC	31.5000	1.95206	34.2604	2.02742	2.7604
		PRIVATE	30.8571	2.15534	33.5714	2.20149	2.7143
TD		PUBLIC	31.2706	2.00231	33.0941	2.37859	1.8235
		PRIVATE	31.3667	2.26645	33.2921	2.58141	1.9254

Table 4.22 show the interaction effect of treatment and school type on science process skills. In all the groups, the mean difference of private school students are higher than that of their counterparts in public school except in GD strategy where the mean difference of public school students (2.7604) was higher than those in private school (2.7143). The trend in the

effectiveness of the treatments followed the same pattern for both public and private schools. This is, IGD > GD > ITD > TD.

Also, the interaction effect of treatment and school type is as shown in figure 8



Covariates appearing in the model are evaluated at the following values: PRESPST = 31.2848

Figure 4.2: Interaction Effect of Treatment and School Type on Science Process Skills

Figure 8 shows that private school students scored higher in IGD and ITD strategy than the public school students.

The interaction effect of treatment and school type is shown on Table 4.23 for 21st century skills. The mean differences of public school students were higher than their private school counterparts in all the strategies except in GD where the mean difference of private school students was higher than their public school counterparts. For public school the trend in the effectiveness of the treatments is IGD > ITD > guided discovery > TD. While, private school follows this trend: IGD > GD > ITD > TD.

Table 4.23: Interaction Effect of Treatment and School Type on 21st century Skills

Treatment	Learning Outcomes	School Type	Mean (x) Scores pre-test (x)	Std Dev SD	Mean (x) Scores Post-test (x)	Std Dev SD	Mean Difference
ITD	21stCentury Skills	PUBLIC	48.0235	2.82412	50.6824	2.80396	2.6589
		PRIVATE	60.2778	1.80866	61.6667	2.52050	1.3889
IGD		PUBLIC	49.5714	2.26230	55.6286	1.76250	6.0572
		PRIVATE	59.8462	1.51911	62.7692	2.27866	2.923
GD		PUBLIC	49.3646	2.50943	51.7396	2.84418	2.375
		PRIVATE	48.9643	2.39571	51.6071	3.08328	2.6428
TD		PUBLIC	49.3113	2.78643	50.5094	2.78173	1.1981
		PRIVATE	48.2000	5.89357	49.5000	3.14862	1.3

Hypothesis $H_0$4: There is no significant interaction effect of treatment and school type on students' learning outcomes.

The summary of table of ANCOVA on Table 4.24 for conceptual understanding show that $p < 0.05$ ($p = 0.047$). Therefore, the null hypothesis was rejected for conceptual understanding. This means that there is significant interaction effect of treatment and school type on conceptual understanding.

Table 4.24: Summary of Analysis of Covariance of treatment, gender and school type on conceptual understanding among chemistry students.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5808.719[a]	16	363.045	187.088	.000	.875
Intercept	1812.807	1	1812.807	934.194	.000	.685
PRECUT (Covariates)	4135.260	1	4135.260	2131.024	.000	.832
TREATMENT	832.364	3	277.455	142.981	.000*	.500
Gender	.664	1	.664	.342	.559	.001
SCHLTYPE	9.115	1	9.115	4.697	.031*	.011
TREATMENT * Gender	3.863	3	1.288	.664	.575	.005
TREATMENT * SCHLTYPE	15.584	3	5.195	2.677	.047*	.018
Gender * SCHLTYPE	.110	1	.110	.057	.812	.000
TREATMENT * Gender * SCHLTYPE	11.745	3	3.915	2.017	.111	.014
Error	832.476	429	1.941			
Total	80489.000	446				
Corrected Total	6641.195	445				

a. R Squared = .875 (Adjusted R Squared = .870)
b. * significant at 0.05

To test for the significance interaction effect of treatment and school type on problem-solving skills is shown on Table 4.25. P value is greater than .05 (.773). Therefore, the hypothesis is accepted for problem-solving skills. There is no significant interaction effect of treatment and school type on problem-solving skills.

Table 4.25: Summary of Analysis of Covariance of treatment, Gender and School Type on problem solving skills among chemistry students

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	7249.564[a]	16	453.098	455.726	.000	.944
Intercept	749.714	1	749.714	754.063	.000	.637
PREPSST (Covariates)	5121.210	1	5121.210	5150.914	.000	.923
TREATMENT	564.290	3	188.097	189.188	.000*	.570
Gender	.332	1	.332	.334	.563	.001
SCHLTYPE	.099	1	.099	.099	.753	.000
TREATMENT * Gender	1.415	3	.472	.474	.700	.003
TREATMENT * SCHLTYPE	1.110	3	.370	.372	.773	.003
Gender * SCHLTYPE	1.108	1	1.108	1.114	.292	.003
TREATMENT * Gender * SCHLTYPE	1.255	3	.418	.421	.738	.003
Error	426.526	429	.994			
Total	65766.000	446				
Corrected Total	7676.090	445				

a. R Squared = .944 (Adjusted R Squared = .942) b. * significant = 0.05 (c) PREPSST = pretest problem solving skills test

To test for the significance interaction effect of treatment and school type on science process skills is shown on table 4.26. P value obtained was less than $p < 0.05$ (.001). Therefore, for science process skills, the null hypothesis was rejected.

Table 4.26: Summary of Analysis of Covariance of Treatment, Gender and School Type on acquisition of science process among chemistry students

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2981.011[a]	16	186.313	365.916	.000	.932
Intercept	12.213	1	12.213	23.986	.000	.053
PRESPST	1716.997	1	1716.997	3372.157	.000	.887
TREATMENT	694.820	3	231.607	454.872	.000*	.761
Gender	.092	1	.092	.180	.671	.000
SCHLTYPE	3.589	1	3.589	7.049	.008*	.016
TREATMENT * Gender	.270	3	.090	.177	.912	.001
TREATMENT * SCHLTYPE	8.081	3	2.694	5.290	.001*	.036
Gender * SCHLTYPE	.827	1	.827	1.624	.203	.004
TREATMENT * Gender * SCHLTYPE	3.107	3	1.036	2.034	.108	.014
Error	218.433	429	.509			
Total	503388.000	446				
Corrected Total	3199.444	445				

a. R Squared = .932 (Adjusted R Squared = .929) b.* significant at 0.05

To test for the significance interaction effect of treatment and school type on 21st century skills is shown on table 4.27. P value obtained was less than $p < 0.05$ (.001). Therefore, for 21st century skills, the null hypothesis was rejected. This means that there is significant interaction effect of treatment and school type on acquisition of 21st century skills.

Table 4.27: Summary of Analysis of Covariance of Treatment, Gender and School Type on acquisition of on 21st century skills among chemistry students

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	6844.960[a]	16	427.810	195.321	.000	.879
Intercept	88.118	1	88.118	40.231	.000	.086
PRE21STCST	2161.934	1	2161.934	987.053	.000	.697
TREATMENT	334.671	3	111.557	50.933	.000	.263
Gender	.445	1	.445	.203	.653	.000
SCHLTYPE	6.797	1	6.797	3.103	.079	.007
TREATMENT * Gender	7.260	3	2.420	1.105	.347	.008
TREATMENT * SCHLTYPE	38.840	3	12.947	5.911	.001	.040
Gender * SCHLTYPE	4.632	1	4.632	2.115	.147	.005
TREATMENT * Gender * SCHLTYPE	10.456	3	3.485	1.591	.191	.011
Error	939.635	429	2.190			
Total	1233295.000	446				
Corrected Total	7784.594	445				

a. R Squared = .879 (Adjusted R Squared = .875) b. PRE21STCST = pretest 21st century

4.1.5 Research Question 5: What is the interaction effect of treatment and gender on chemistry students' learning outcomes?

$H_0$5: There is no significant interaction effect of treatment and gender on students' learning outcomes in chemistry.

Table 4.28: Interaction Effect of Treatment and Gender on Conceptual Understanding

Treatment	Learning Outcomes	School Type	Mean (x) Scores pre-test (x)	Std Dev SD	Mean (x) Scores Post-test (x)	Std Dev SD	Mean Difference
ITD	Conceptual Understanding	Male	9.4643	3.30820	13.8214	2.74430	4.3571
		Female	10.0000	3.34274	14.0426	2.80494	4.0426
IGD		Male	8.5147	3.97564	15.8088	3.27932	7.2941
		Female	8.2667	4.18273	16.2667	3.01109	8.0000
GD		Male	8.0580	3.92909	12.2609	3.67284	4.2029
		Female	8.6545	4.04245	12.5818	3.85713	3.9273
TD		Male	8.7197	3.65283	13.0833	3.79722	4.3636
		Female	9.0879	3.79342	12.5549	3.94643	3.467

The interaction effect of treatment and gender is shown on Table 4.16 for conceptual understanding. The mean differences show that male students performed better in all the teaching strategies except IGD where female students performed better than their male counterpart. However, IGD is the most effective teaching strategy for both male and female for conceptual understanding.

The test of significance on Table 4.22 shows no significant interaction between treatment and gender on conceptual understanding ($p > 0.05$). $p = .575$. The null hypothesis is therefore accepted for conceptual understanding.

Table 4.29: Interaction Effect of Treatment and Gender on Problem solving Skills

Treatment	Learning Outcomes	School Type	Mean (x) Scores pre-test (x)	Std Dev SD	Mean (x) Scores Post-test (x)	Std Dev SD	Mean Difference
ITD	Problem solving Skills	Male	8.3750	3.78784	32.7321	2.37786	24.3571
		Female	8.8936	3.95757	33.8298	2.13988	24.9368
IGD		Male	8.2353	2.96808	36.2794	2.07217	28.0441
		Female	8.9333	2.46306	35.6667	2.82000	26.7334
GD		Male	8.8406	3.81415	34.0870	2.16074	25.2464
		Female	8.5636	4.00816	34.1273	1.99123	25.5637
TD		Male	7.4507	2.85752	33.6742	2.78097	26.2235
		Female	8.0275	3.75703	33.2198	2.51318	25.1923

Table 4.29 show the mean differences of male and female students taught by different strategies. IGD is the most effective strategy for teaching problem solving skills for both male and female chemistry students as they both had highest mean difference.

However, the test for significance showed no significant interaction effect as shown in Table 4.25 ($p > 0.05$). The null hypothesis is accepted for problem solving skills.

Further, there were no significant interaction effect of treatment and gender as revealed in Tables 4.26 and 4.27 for science process skills and 21st century skills. The null hypothesis 5 is therefore accepted for all the four learning outcomes in chemistry.

4.1.6 Research Question 6: What is the interaction effect of school type and gender on students' learning outcomes?

$H_0$6: There is no significant interaction effect of school type and gender on students' learning outcomes.

The significant values of 0.57, 0.292, 0.203 and 0.147 for conceptual understanding, problem-solving, science process skills and 21st century skills respectively on summary of ANCOVA Tables 4.24, 4.25, 4.26 and 4.27 are not significant at $p< 0.05$. Therefore, for all the four learning outcomes, there was no significant interaction effect of school type and gender. The null hypothesis was accepted.

4.1.7 Research Question 7: What is the interaction effect of treatment, gender and school type on students' learning outcomes?

$H_0$7: There is no significant interaction effect of treatment, gender and school type on students' learning outcomes.

There was no significant effect of treatment on gender for all the four learning outcomes but there was significant effect of treatment and school type on conceptual understanding and science process skills and 21st century skills but, there was no significant effect of treatment and school type on problem-solving skills. However, the significant interaction effect of treatment, gender and school type as shown on Tables 4.24, 4.25, 4.26 and 4.27 for conceptual understanding, problem-solving skills, science process skills and 21st century skills are .111, .738, .108 and .191 respectively. All these show no significant interaction effect of treatment, school type and gender on the four learning outcomes. Therefore, the null hypothesis was accepted.

4.2 Summary of the findings

The findings of this study are as follows:

(1) There are significant main effects of treatment on learning outcomes. IGD significantly differs from ITD, Guided Discovery and Teacher Demonstration on all the learning outcomes. IT-integrated Teacher demonstration was significantly different from Teacher Demonstration on all the learning outcomes but, was not significantly different from Guided Discovery for conceptual understanding, science process skills and 21^{st} century. The significance was in favour of Guided Discovery for problem-solving skills.

(2) IT-integrated Guided Discovery was the most effective for all the learning outcomes

(3) Guided Discovery strategy was more effective than IT-integrated Teacher Demonstration on problem-solving skills and science process skills.

(4) IT-integrated Teacher Demonstration was more effective than Guided Discovery in teaching 21^{st} century skills

(5) Public school students performed higher than their counterparts in private school in conceptual understanding, problem-solving skills and 21^{st} century skills after the treatment. But, both performed equally in science process skills.

(6) School type significantly influenced chemistry students' conceptual understanding and science process skills but there was no significant influence of school type found on problem-solving skills and 21^{st} century skills acquisition among chemistry students.

(7) There was no significant influence of gender found on all the learning outcomes in chemistry.

(8) IGD strategy was effective for both male and female students on all the chemistry learning outcomes considered.

(9) There were significant interaction effects of treatment and school type on chemistry students' conceptual understanding, science process skills and 21^{st} century skills. But,

no significant interaction effect of treatment and school type was found on chemistry students' problem-solving skills acquisition.

(10) There was no interaction effect of treatment and gender, school type and gender and treatment, school type and gender on chemistry students' learning outcomes.

4.3 Discussion of Findings

The findings of this study are discussed in line with the specific objectives.

Main Effects of IT-Integrated Teaching Strategies on Chemistry Students' Learning Outcomes.

Conceptual Understanding

There are significant main effect of the teaching strategies on chemistry students' conceptual understanding, problem solving skills, science process skills and 21st century skills. The teaching strategy that was most effective for all the four learning outcomes was Information Technology-integrated Guided Discovery (IGD) based on the mean difference as shown on Table 4.1.

IGD significantly differed from ITD, GD and TD for conceptual understanding; ITD also differed significantly from GD and GD was significantly different from TD in improving students' conceptual understanding. The pattern of the teaching strategies in enhancing conceptual understanding in the difficult topics followed this trend; IGD > ITD > GD > TD

The reason why IT-integrated Guided Discovery was found to be most effective, may be due to the fact that guided discovery on its own has been confirmed to be effective in science teaching (FME, 2007) as it applies the principles of effective questioning, appropriate directives and it is activity-oriented. Integrating technology into this method obviously increased the effectiveness of the strategy on the learning outcomes. Integration of IT into teacher demonstration also improved the performance of the students in the conceptual understanding more than the teacher demonstration alone because research has shown that integration of IT into instruction promotes students’ learning outcomes. Anula (2006) and Chittleborough and Treagust (2007) identified pedagogical and technological features of teaching chemistry through computer software as contributory to the effect of the integration observed in the students’ performance. Computer simulations involved in the packages may have provided learners the conceptual assistance that led to enhanced performance and retention of concepts learnt.

The two information technology-integrated teaching strategies were more effective than the two non technology-integrated strategies in improving conceptual understanding in chemistry. This finding agrees with Su (2007) that multimedia technology can have a facilitating function in the process of learning which helps students acquire a better understanding of targeted chemistry concepts and promotes a positive attitude toward chemistry learning. Multimedia technology provided powerful means for fostering chemical understanding. Also, Oloyede (2010) and Olorundare & Oyelekan (2009) affirm that integration of Information Technology into classroom instructions improved learning outcomes in chemistry. The finding is in agreement with Dori & Barak (2000) and Paul (2002) that found that the integration of ICT to chemistry teaching build mental link which enhances meaningful chemistry learning and environment. Therefore, ICT integration has a significant impact on chemistry students’ conceptual understanding.

Problem-solving Skills

The effectiveness of the teaching strategies follows the following order for students’ Problem–solving skills; IGD > GD > ITD > TD

Information Technology-integrated Guided Discovery (IGD) was the most effective teaching strategy followed by guided discovery Strategy (GD). This agrees with Hollingworth &

McLoughlin (2001) who established the fact that information technology rich environment is a proactive approach that creates real life anchors for the development of problem solving skills and enable students to explore, test and review their own strategies. GD was more effective than Information Technology-integrated teacher demonstration strategy (ITD) and ITD was more effective than Teacher demonstration (TD) in enhancing students' problem-solving skills. The better performance in problem solving and science process skills of students taught with guided-discovery teaching strategy compared with those taught with IT-Integrated Teacher Demonstration and Teacher Demonstration strategies underscores the importance of greater involvement of the learners in the teaching-learning process and the relative ineffectiveness of the Teacher Demonstration method in the teaching and learning of science (Nwachuku & Nwosu, 2007).

Science Process Skills

The effectiveness of the teaching strategies for science process skills followed this trend;
IGD > GD > ITD > TD. This is the same pattern as in the problem-solving skills. This performance is in agreement with the explanation of Nwachuku & Nwosu, (2007) that students are more involved in the teaching learning process in guided discovery because it is student-centred. It also follows that skills are best acquired by hands on activities.

21st Century Skills

The effectiveness of the teaching strategies for 21st century skills followed a slightly different pattern from problem-solving skills and science process skills IGD > ITD > GD > TD. Information Technology-integrated guided discovery was the most effective followed by the information technology-integrated teacher demonstration.

Influence of School Type on Students' Learning Outcomes

Public school students performed better than their private school counterparts in conceptual understanding, problem-solving skills and 21st century skills (Table 4.9). The influence was significant only on conceptual understanding (Table 4.14). This finding was in agreement with Naser (2008) who evaluates the effectiveness of ICT on student school performance and found that public school students outperformed their private school counterparts in baccalaureate examinations. However, the finding was contrary to the findings of Olasheinde and Olatoye (2014) where private school students were better in science achievement than their counterparts in the public schools and Abari & Odunayo (2012) who found no significant difference in the academic performance of students in the SSCE between the public and private senior secondary schools. The finding of this study may be due to the fact that private school students are more familiar with using technology tools in regular classroom setting, whereas, it is a new innovation for public school students. So, it arouses their interest and this led to a better performance.

Private school students however performed better than public school students in science process skills acquisition and the difference is significant in agreement with the findings of Olasheinde and Olatoye (2014). However, no significant influence of school type was found on problem-solving and 21st century skills acquisition among chemistry students. (Table 4.11). This finding agrees with the finding of Abari & Odunayo (2012), found no significant difference between the performance of students in public and private senior secondary schools in Senior Secondary Certificate Examination.

Influence of Gender on Students' Learning Outcomes

With respect to performance by gender, IGD was the most effective for both male and female students but male students performed better in conceptual understanding in all the strategies except IGD. Male students generally performed better than female students in the four learning outcomes. This finding agrees with many studies that showed that male students consistently achieve higher than their female counterparts in science (Okonkwo & Eke, 2005; Eriba & Ande, 2006; Njoku, 2007; Okigbo & Akusoba, 2009). However, there was no significant influence of gender on all the four learning outcomes was in agreement with Iorchugh, (2006) and Udo, (2006) who found no significant effect of gender on students' achievement in science. The comparable performance of the males and females observed agree with earlier findings by Nwachuku and Nwosu (2007) and Adeoye (2016) indicate that gender was not a strong determinant of students' academic achievement in chemistry rather the instructional approach.

Interaction Effects of Treatment and Gender

There was no significant interaction effect of treatment and gender on all the four learning outcomes in chemistry. That is the teaching strategies and gender has no influence on students' learning outcomes. This implies that if effective strategies are effectively utilised in chemistry teaching, students would perform better in the learning outcomes irrespective of gender. This is in agreement with the results of Olasheinde and Olatoye (2014) and Adeoye (2016) which showed no significant interaction effect of teaching strategies and gender on chemistry students' learning outcomes.

Interaction Effects of Treatment and School Type

There were significant interaction effects of treatment and school type on chemistry students' conceptual understanding, science process skills and 21^{st} century skills. But, no significant interaction effect of treatment and school type was found on chemistry students' problem-solving skills acquisition.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

This chapter undertakes a summary of this study. Some conclusions are drawn while some useful suggestions for further studies are proffered.

5.1 Summary

The focus of the study was on the development of information technology-integrated guided discovery (IGD) and information technology-integrated teacher demonstration (ITD) teaching packages to teach four difficult topics in chemistry. The four difficult topics are; Mole concept, Electrolysis, Oxidation Reduction (redox) reactions and Rates of reactions. The impact of the packages was assessed on Chemistry students' conceptual understanding and acquisition of problem-solving skills, science process skills and 21st century skills in Lagos State, Nigeria.

Furthermore, the study developed operational guides for the teaching packages and the two control strategies (non-IT-integrated strategies) namely; Operational Guide for IT-Integrated Teacher Demonstration (OGITD), Operational Guide for IT-Integrated Guided Discovery (OGIGD), Operational Guide for Guided Discovery Strategy (OGGD) and Operational Guide for Teacher Demonstration Strategy (OGTD) which show the step by step framework of interactions of the elements of activities that would take place during the teaching of each of the topics in chemistry.

The population comprised all SS2 Chemistry students in Lagos State. Four hundred and forty-six (446) Chemistry students from twelve (12) intact classes of public and private schools from Education Districts II and III were the sample for the study. The study adopted a 4×2×2 pre-test post-test non-equivalent control group quasi experimental research design, the study examined the main effects of the treatments, school type and gender and the interaction effects of the variables on chemistry students' conceptual understanding, problem-solving skills, acquisition of science process skills and acquisition of 21^{st} century skills. Four major instruments: Chemistry Conceptual Understanding Test (CCUT), Problem-solving Skills Test (PSST), Science Process Skills Test (SPST) and 21^{st} Century Skills Test (21^{st} CST) were used to collect data. Data were analysed using descriptive statistics and analysis of covariance (ANCOVA). Bonferoni post-hoc analysis was used to verify the direction of significance difference where it exists.

The major findings are:

- IT-integrated Guided Discovery was the most effective for all the learning outcomes. There were significant main effects of ITD, IGD, on chemistry students' learning outcomes.
- Comparing the information technology-integrated and non-information technology-integrated strategies, IGD was better than GD while, ITD was better than TD.
- There was significant main effect of school type on chemistry students' conceptual understanding and science process skills but no significant effect of school type was found on chemistry students' problem-solving skills and 21^{st} century skills.
- There was no significant influence of gender on any of the learning outcome.

Other findings are which relate to the objectives of the study are:

- Findings also revealed significant interaction effects of treatment (ITD and IGD) and school type on chemistry students' conceptual understanding and science process skills and 21^{st} century skills.
- No significant interaction effect of treatment and gender;
- No significant interaction influence of school type and gender;
- No significant interaction effect treatment, school type and gender on the four chemistry students' learning outcomes.

The study established that an Information Technology-integrated teaching strategy promotes chemistry students' learning outcomes better than strategy without technology integration. Integration of technology into strategies of teaching chemistry in secondary schools fosters better understanding of the difficult topics and promotes acquisition of skills which in turn would lead to better academic performance in chemistry.

The study also established that when schools are adequately equip with teaching learning resources public school students would perform equally and even better than their counterparts in private schools. Difference in the performances of public and private school students is not a function of who owns the school but a function of facilities and resources available for teaching and learning

5.2 Conclusions

The study established that Information Technology-integrated guided discovery and Information Technology-integrated teacher demonstration teaching strategies were both effective at improving senior secondary school students' achievement in conceptual understanding and acquisition of problem-solving skills, science process skills and 21st century skills. From the findings of the study, integration of IT into the teaching strategies improved public school students' conceptual understanding, acquisition of problem solving skills and 21st century skills in chemistry better than it did for their private school counterparts. The use of technology in classroom teaching motivated and encouraged the public school students more than those in private schools.

5.3 Contributions to Knowledge

The following are the contributions of the study to knowledge:

(1) The study developed and validated the treatment software packages– the Information Technology-integrated Guided Discovery (IGD) and the Information Technology-integrated Teacher Demonstration (ITD) as effective tools for teaching some of the difficult topics in chemistry.

(2) The 6 stages of ASSURE model used in developing The IT-integrated Packages serve as alternative ways of organising the contents of the difficult topics into teaching and learning units (activities) which provided learning experiences that enhanced meaningful understanding of the concepts may serve as appropriate instructional resources for chemistry teaching.

(3) The study provided empirical evidence that integration of IT into strategies of instructions promote active student participation, foster scientific knowledge and skills acquisition which are all necessary for students to acquire meaningful learning.

(4) The study ascertained and provided empirical evidence that IT-integration into instructions enhanced students' understanding of difficult topics in chemistry and fostered acquisition of problem-solving skills, science process skills and 21st century skills.

5.4 Recommendations

Based on the results obtained and discussed in this study, the following recommendations are hereby made:

(1) Integration of technology into regular classroom instruction is recommended to chemistry teachers for the teaching of Chemistry in Senior Secondary Schools for better academic achievement in Chemistry.

(2) The use of Information Technology-integrated teaching strategies is recommended for Chemistry teachers for better understanding of scientific concepts and skills acquisition to enhance meaningful learning.

(3) For effective integration of technology into teaching strategies, government should equip the schools with adequate technology tools for teaching and learning.

(4) Government should regularly organize in-service and training programs for teachers' professional development on the effective integration and use of technologies and information technology-integrated strategies in regular classroom through seminars, workshops and conferences.

(5) Government should ensure effective implementation of guided discovery approach and integration of technology into the strategy to teach Chemistry in particular through regular visits to secondary schools by educational monitoring team.

5.4 Suggestions for further Studies

This study should be replicated in other states of the Federal Republic of Nigeria and in other science subjects such as Biology and Physics. Other moderator variables such as school location (rural and urban), mathematical ability and socio-economic background should be investigated.

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APPENDIX I

CHEMISTRY CONCEPTUAL UNDERSTANDING TEST (CCUT)

INSTRUCTION: the test is to measure your conceptual knowledge in electrolysis, redox reactions, chemical kinetics and mole concept in Chemistry. Kindly respond appropriately to all the items. Your responses will be confidentially treated.

NAME:

SEX: Female [ ] Male [ ] Time: 2 hours

NAME OF SCHOOL:

TYPE OF SCHOOL: Private School [ ] Government [ ]

1. (a) State the substance that oxidized in the reaction represented by the following equation.

$$3Cu + 8HNO_3 \longrightarrow 3Cu(NO_3)_{2(aq)} + 2NO_{(g)} + H_2O_{(g)}$$

(b) Consider the electrochemical cell represented: $Zn_{(s)} + Zn_{(aq)} // Cu^{2+}_{(aq)} + Cu(s)$. Write half equation to describe the reactions occurring in the cell.

(c) Consider the reaction:

$$CuO + CO \longrightarrow Cu + CO_2$$

Which of these substances is an oxidizing agent? Explain your reasons.

2. (a) What is the reducing agent in the reaction represented by the following equation?

$$Fe^{3+}_{(aq)} + H_2S_{(g)} \longrightarrow 2Fe^{2+}_{(aq)} + 2H^+ + S_{(s)}$$

(b) Write the balanced half equations for the following redox reaction;

$$Mg_{(s)} + Fe^{2+} \longrightarrow Mg^{2+} + Fe_{(s)}$$

(c) Vividly explain why reducing agents change a solution of acidified potassium tetraoxomanganate (VII), $KMnO_4$, from purple to colourless.

3. (a) The collision theory suggests that for two particles to react, they must collide. What two factors determine whether or not the collision would lead to formation of products?

(b) Draw an energy profile diagram to illustrate a catalysed exothermic reaction and label parts of the curves that represent activated complex, activated energy and enthalpy change.

(c) Explain how the rate of reaction is affected by addition of a catalyst and increase in temperature.

4. Two gaseous reactants A and B were placed in a reaction vessel in a dim room.

The reactions were known to be photocatalytic. They react as shown

$$A_{(g)} + B_{(g)} \longrightarrow C_{(s)} + D_{(g)} \quad \Delta H = -210 kJmol^{-1}$$

(a) State the substance that is the solid state in the reaction

(b) Draw an energy profile for the reactions using reactants, products, activated complex, activated energy and enthalpy change.

(c) Describe the effect of the rate of reaction when temperature and concentration of A are doubled.

5. (a) What is the mass of 1 mole of O_2

(b) How many atoms of oxygen are there in 18g of water?

(c) What is the mass of 4 molecules of water?

6. (a) How many atoms of potassium make up one MOLE ?

(b) How many moles of sodium atoms are there in $12.04 x 10^{23}$ of sodium atoms?

(c) What is the mass of 1 mole of $Ca(OH)_2$ (Ca= 40, O= 16, H= 1)?

7. A solution of copper II tetraoxosulphate(VI) was electrolysed using copper cathode and platinum anode.

(a) Which of the electrode will have increase in mass?

(b) Write a chemical equation for the reaction at the cathode

(c) State the effect of electrolysis on the nature of electrolyte. Give reasons for your answers.

8. (a) What are the substances discharged at each electrode when dilute sodium chloride electrolysed using graphite electrodes?

(b) Write balanced half reactions at cathode and anode for the reaction in 8a.

(c) Explain why manganese conducts electricity in the solid state but manganese chloride conducts only when molten or in solution?

APPENDIX II

PROBLEM SOLVING SKILLS TEST (PSST)

INSTRUCTION: the test is to measure your problem solving skills in electrolysis, redox reactions, chemical kinetics and mole concept in Chemistry. Kindly record all the details of your thinking as you solve the problems.

Your responses will be confidentially treated.

NAME:

SEX: Female [ ] Male [ ] Time: 1 hours

NAME OF SCHOOL:

TYPE OF SCHOOL: Private School [ ] Government [ ]

1. Given the equation below, what mass of ammonia would be produced from 1.0 mole of H_2 and excess nitrogen?

   $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

2. Consider the equation for the reaction

   $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} \quad \Delta H = -92kJmol^{-1}$

   Explain the effect of increase in pressure and increase temperature on the reaction.

3. When aqueous copper (II) tetraoxosulphate (VI) was electrolyzed between copper

electrodes, masses in grams of the electrodes before experiment were the anode 9.20g and the cathode 7.75g. After the experiment, it was found that the mass in grams of copper anode was6.00g. Calculate the mass in grams of copper cathode at the end of the experiment.

4. What is the change in the oxidation number of phosphorus in the reaction represented as?

$$4P_{(s)} + 5O_2 \longrightarrow 2P_2O_{5\,(g)}$$

5. State the substance that oxidized in the reaction represented by the following equation.

$$3Cu + 8HNO_3 \longrightarrow 3Cu\,(NO_3)_{2(aq)} + 2NO_{(g)} + H_2O_{(g)}$$

6. The collision theory suggests that for two particles to react, they must collide. What two factors determine whether or not the collision would lead to formation of products?

7. A solution of copper II tetraoxosulphate VI was electrolysed using copper cathode and platinum anode. State the effect of electrolysis on the nature of electrolyte. Give reasons for your answer.

8. How many moles are there in 20g of $CaCO_3$?

APPENDIX III

SCIENCE PROCESS SKILLS TEST (SPST)

INSTRUCTION: Kindly response to the items in this test. Section A is hands on activities while section B is free answer questions to test your basic science process skills acquisition in the topics covered (rate of reaction, mole concept, oxidation–reduction reaction and electrolysis). Your responses shall be treated confidentially.

NAME:

SEX:

NAME OF SCHOOL:

SECTION A

TEST ITEM 1

You are provided with a balance and containers of different substances:

A. Sugar, B. salt C. copper(II)tetraoxosulphate (VI) D. marble and E. sand

(i) Record the details of the observed characteristics of the substances

(ii) Classify the substances in two (giving your reasons)

(iii) Write the procedure you will follow to differentiate the sample by mass

(iv) Write the procedure you will follow to find the number of moles of each sample

(v) Mix each sample in $50cm^3$ of water, what inferences can you make from your observation?

TEST ITEM 2

You are provided with 2 beakers ($100cm^3$), 2M HCl, 10 g of sample A(marble chips) and 10g of sample B (powdered marble).

(i) Record your observations of sample A and sample B.

Put $100cm^3$ of 2M HCl in each of the 2 beakers. At the same time add sample A into one beaker and sample B into the other.

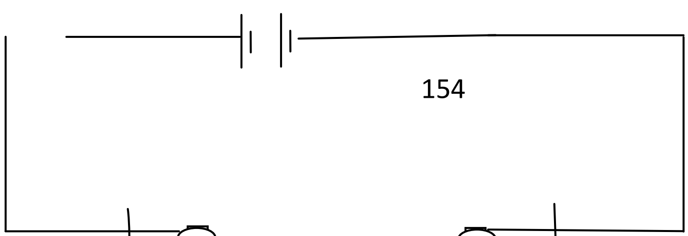
(ii) Observe and record the rate and duration of effervescence of the 2 beakers

(iii) What is your inference based on your observations?

(iv) Predict what will happen if cube sugar and powdered sugar were used in place of samples A and B.

TEST ITEM 3

You are provided with the experimental set up shown in the diagram below. Consider this experimental set-up and answer the following questions.



WWW

A

\+ –

C — Copper cathode

$CuSO_4$ solution

Copper anode

(i) What is the experimental set-up called?

(ii) Observe and explain what happen at each electrode

(iii) Predict the concentration of the electrolyte after electrolysis.

TEST ITEM 4

You are provided with potassium iodide solution and iron (III) tetraoxosulphate (VI). Add a few drops of potassium iodide to a little iron (III) tetraoxosulphate (VI).

(i) Observe and record the colour change

(ii) Explain what happened in the reaction

(iii) Infer from your observation oxidizing and reducing agent

(iv) Predict half equations for both oxidation and reduction reactions

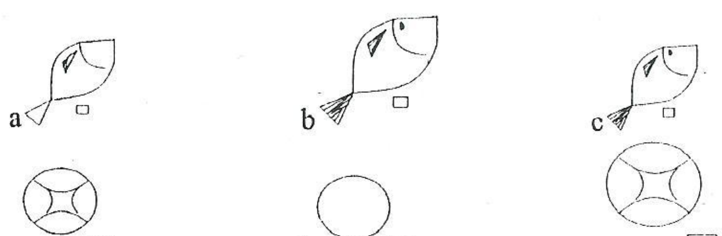
SECTIONB

Instruction: Read the questions and statements below, and answer as best as you can.

A. **Observation**

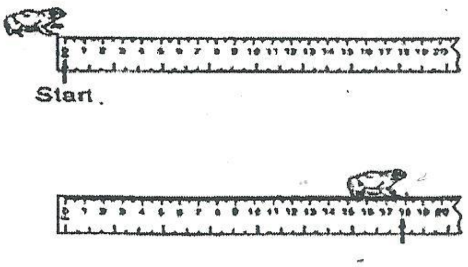
Instruction: Tick the odd one out.

1.



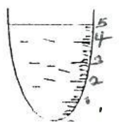
B) **Measurement**

1. Using the picture, which measurement is closes to how far the frog jumped?

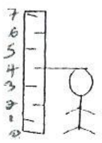


A. 12 centimeters (cm)
B. 14 centimeters (cm)
C. 18 centimeters (cm)
D. 20 centimeters (cm)

A.

2. 

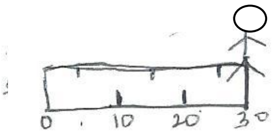
The volume of water in the cyclinder ______________
a. 1mm b. 5mm c. 0mm

3. 

Wht is the height of the boy in the diagram? (a) 2m (b) 6m (c) 4m

4 

The volume of water in the bowl is ___________ (a) 0m (b) 1m (c)
2

5. 

At what distance did Shola travelled? (a) 50mm (b) 10mm (c) 30mm

C.

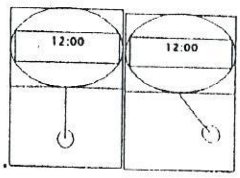
C. **Predicting.**

1.34PM

1. Considering the time,

a) The sun is setting
b) The sun has risen
c) The star is shining

C.
C.

2. 

From the object, the object describes that ... a) the ball is moving b) theballl is not moving c) the ball is static.

3. Segun couldn't see the blackboard from afar, what should he wear in order to see very clearly?
a) glasses b) dress c) suite
4. The floor was slippery and he slipped off and fell. What happened? a) Rain fell b) Sunny c) Misty
5. Why is Bimbo dancing? a) She is tired b) she is hungry c) She is happy.

D. **Inferring**

Choose the correct answer/rom the options given.

1. A solution of ash turns a certain colored paper to blue, what can you say about the ash solution? a) neutral b) acidic c) basic
2. Ade tries to see through the louvres but couldn't see anything inside the room therefore the louvres was a) ordinary b) tinted c) white
3. Shade added lots of pepper to the food she cooked, therefore the food was __ a) peppery b) sweet c) salty.
4. When iodine solution is added to a boiled yam, the yam changes to blue-black. That means…. a) Starch is present b) protein is present c) fat & oil present.
5. When vegetable oil is poured on a white paper, the paper becomes translucent, which means
   a) carbohydrate is present b)protein is present c) fat & oil is present.

E. **Classification**

Consider the following classes of items and tick the odd one out

1.	a) books	b) pens	c) biro	d) spoon
2.	a)cat	b) dog	c) ant	d) chair
3.	a)orange	b) mango	c)rice	d) pineapple
4.	a) phone	b) television	c)plastic	d)radio
5.	a) chicken	b) mat	c) Pork	d) beef

APPENDIX IV

21st Century Skills Test (21st CST)

INSTRUCTION: the test is to measure your skills acquisition in ICT literacy, communication, collaboration, leadership and critical thinking.

Your responses will be confidentially treated.

NAME:

SEX: Female [ ] Male [ ] Time: 1 hour

NAME OF SCHOOL:

TYPE OF SCHOOL: Private School [ ] Government [ ]

ICT RATING SCALE QUESTIONNAIRE

Kindly rate your skills in the use of ICT on the following scale

Excellent = 5

Above average = 4

Average = 3

Below average = 2

Poor = 1

S/N	Items	1	2	3	4	5
1	Rate your overall skills of computer expertise					
2	Rate your skills in handling the mouse					
3	Rate your skills in keyboarding					
4	Rate your educational use of computer					
5	Rate your knowledge of software application					

Collaboration Rating Scale

This is a straightforward self-test, simply designed to highlight your strengths and weaknesses.
Score yourself using the following measure: 1= I have trouble with this, 2= I do this reasonably well,
3= I see this as a strength of mine.

S/N	Items	1	2	3
1	I look for common points of agreement			
2	I often compliment my colleagues			
3	I think before I speak			
4	I don't take differences of opinion personally			
5	I don't need to be right all the time			
6	I don't attack my partner as a person, but focus on the issue			

Source: Adapted from the gifted way. How effective a collaborator are you?

By Christopher J. Coulson, August 29th, 2009.

http://www.thegiftedway.com/dynamic-living-archive/how-effective-a-collaborator-are-you.

Retrieved on 28th June, 2013.

LEADERSHIP SKILLS TEST

Simply choose the response that fits your best to rate your leadership skills.

Always Sometimes Never

1. I lead my group members by example whenever I work in group..	◯	◯	◯
2. I listen carefully to my group members whenever a lead and encourage them to express their opinions.	◯	◯	◯
3. I resolve conflict as it occurs and consider the best interests of all concerned.	◯	◯	◯
4. I have best interests of my group members in mind whenever I lead.	◯	◯	◯
5. I encourage initiative, involvement and innovation from my group members whenever I lead.	◯	◯	◯

Source: Adapted from Leadership assessment quiz/Evaluate leadership skills test.
http://www.optimalthinking.com/leader-assessment.php
Retrieved on 6/30/2013

CRITICAL THINKING TEST

1. Mr. Musa's age is inversely proportional to his friend's age, Sule. When Mr. Musa was 4 years, Sule was 2 years. What is Mr. Musa's age when Sule is $8^1/_2$ years?
   A. $4^1/_2$ years B. 16 years C. halve Sule's age D. Double's Sule's age.
2. A balloon can hold $100cm^3$ of air before bursting. The balloon contains $97.5cm^3$ of air at 5^0c. Will it burst when it is taken into a room of 25^0c? (Assume that the pressure of the gas in the balloon remains constant).
   A. The balloon will not burst because it contain the same volume of air
   B. The balloon will burst because the gas pressure remains constant.
   C. The balloon will burst because of the temperature increase to 25^0c

D. The balloon will burst because the volume of the air in the balloon will increase beyond its capacity when the temperature increases to 25^{0c}.

3. 1cm3 of methylated spirit was mistakenly poured on Toun's palm. Toun felt a cool sensation on her palm as the methylated spirit evaporated. Why did she feel the cool sensation?

A. Because the methylated spirit evaporated
B. Because cool the sensation was from her hand
C. Because evaporation results in the escape of energetic particles from the methylated spirit body, the average kinetic energy of the liquid is lowered
D. Because the kinetic energy of the methylated spirit increases it's evaporated.

4. A mixture contains three colourless substances X, Y, Z. the solubility of these substances in different solvents is as follows:

	Water	Ethanol	Ether
X	Soluble	Insoluble	Insoluble
Y	Insoluble	Soluble	Very soluble
Z	Soluble	Soluble	Insoluble

What would be the quickest way to get some of the substance X from the mixture X+Y+Z?

A. Addition of water to the mixture of X, Y and Z.
B. Addition of water plus ether to the mixture of X, Y and Z.
C. Addition of ethanol to the mixture of the X, Y and Z.
D. Addition of Ether to the mixture of X, Y, and Z.

5. In a country where temperature falls below 0^0c. During such weather condition, the government of that country sprinkles salt on the icy roads and people add anti-freeze to their car radiators. Why do you think they do these?

A. Because the addition of salt to the icy roads prevent freezing.
B. Because icy road is slippery and could cause accident
C. Because addition of antifreeze to the car radiators prevent the water in them from freezing and salt sprinkling on the icy road is for safety of cars.
D. Because antifreeze prevent the water in the radiators from freezing and sprinkling of salt on the icy roads is to lower the melting point of ice so that it melts.

Communication Skills Test

Kindly respond to the following statements by ticking the most appropriate to you.

Most of the time = 1

Often = 2

Sometimes = 3

Rarely = 4

Never = 5

s/n	Items	1	2	3	4	5
1.	I can tell when someone does not understand what I am saying.					
2.	I manage to express my ideas clearly.					
3.	I find it had to express my feelings to others.					
4.	I have difficulty putting my thoughts into words.					
5.	If I don't understand someone's explanation at first, I feel stupid asking for clarification.					

http://pschologytoday.test.physchtests.com/bin/transfer,

Retrieved on 6/30/2013

APPENDIX V

CHEMISTRY CONCEPTUAL UNDERSTANDING TEST (CCUT) MARKING GUIDE

1(a) Copper, Cu 1mk

(b) $Zn_{(s)} \longrightarrow Zn^{2+}_{(aq)} + 2e^-$ (Oxidation) 1/2mk

$Cu^{2+}_{(aq)} + 2e^- \longrightarrow Cu$ (reduction) 1/2mk

(c) CuO is the oxidizing agent. CuO donated oxygen to CO to become CO_2. CUO has undergone a reduction process. It has become Cu while CO has undergone an oxidation process and become CO_2. 1mk

2.(a) H_2S is reducing agent. (It has undergone oxidation to become S. H_2S has been removed from H_2S to become S). 1mk

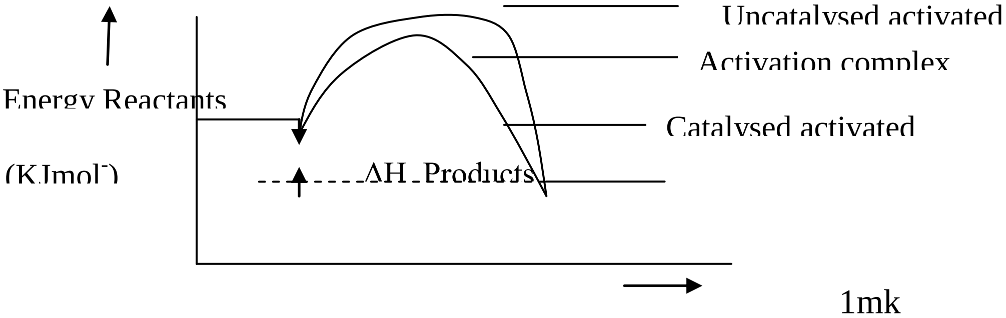
(b) $Mg_{(s)} \longrightarrow Mg^{2+} + 2e^-$ (Oxidation) 1/2mk

$Fe^{2+}_{(aq)} + 2e^- \longrightarrow Fe_{(s)}$ (Reduction) 1/2mk

(c) Reducing agents change a solution of acidified potassium tetraoxomangessse (VII); $KMnO_4$, from purple to colourless. This is because the tetraoxomanganate VII ion, MnO_4^-, which is purple in colour, is reduced to the manganese (II) ion, Mn^{2+} which is colourless. 1mk

3 (a) I. There must be effective collision because not all collision leads to formation of product 1/2mk

II. Energy of collision must be equal or greater than activated energy 1/2mk



1mk

Reaction Pathway

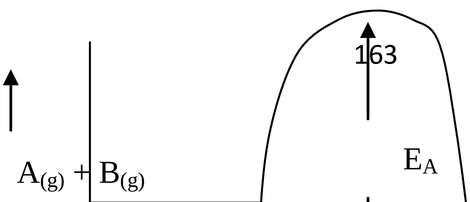
3(c) **Effect of increase in temperature on rate of reaction.**

Increasing the temperature of a system can lead to an increase in reaction rate in two ways. When the temperature is raised, energy in the form of heat is supplied to the reactant particles, so that;

- the number of particles with energies equal to or greater than the activation energy increases;
- the average speed of the reactant particles increased due to the increase in kinetic energy. The increase on kinetic energy causes high frequency of collision.

  As a result, the number of effective collisions increases and the reaction proceeds at a faster rate. 1mk

4(a) C (carbon) is in the solid state 1mk



(b)

1mk

(c) When pressure A is doubled, reactant particles will collide more often if they are crowded in a small space, i.e. frequency of collision is dependent upon pressure. An increase in pressure, results in a corresponding increase in effective collision of the particles of A and hence in the reaction rate. 1mk

5(a) 1 mole of oxygen gas = O_2 (O =16)

$16 \times 2 = 32g$ 1mk

(b) water (H_2O) (H= 1, O = 16)

$H_2O = 2\times1 + 16\times1 = 18g$

1 atom of oxygen 1mk

(c) 4 molecules of water = $4H_2O$.

$4\times18 = 72g$ 1mk

6(a) 1 atom of potassium = 1 mole 1mk

(b) 1 mole of sodium = 6.02×10^{23}

X mole = $12.04\times10^{23} \div 6.02\times10^{23}$ = 2moles 1mk

(c) $Ca(OH)_2$ (40+ $(16+1)_2$ = 74g

7(a) Cathode electrode

(b) $Cu^{2+}{}_{(aq)} + 2e^- \longrightarrow Cu_{(s)}$

(c) The electrolyte will be acidic. Concentrations of H^+ and SO_4^{2-} increase because Cu^{2+} is discharged being lower than H^+ in the electrochemical series. CU is deposited at cathode and H^+ remains in the solution. At the anode OH^- is discharged as hydrogen gas and water being higher than SO_4^{2-} in the electrochemical series and SO_4^{2-} remains in the solution.

8(a) Chlorine gas will be discharged at the anode while hydrogen gas will be discharged at the cathode.

(b) At cathode | At anode

$H^+ + e \longrightarrow H$ | $Cl^- - e^- Cl \longrightarrow$

$H + H \longrightarrow H_2$ | $Cl + Cl \longrightarrow Cl_2$

(a) Manganese conducts electricity n the solid state because mental nuclei have sea of mobile (valence) electrons which conducts the current. Manganese (II) chloride conducts only when in solution or molten because the conduction is by mobile ions.

APPENDIX VI

PROBLEM SOLVING SKILLS TEST (PSST) MARKING GUIDE

1.$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

Answer: 1mole Nitrogen gas react with 3 moles of hydrogen gas to produce 2 moles of ammonia

(2×14)g of N_2 + 3(2×2)g of H_2 produce 2(14 +(3×2)g of NH_3 **1mk**

12g of H_2 produced 40g of NH_3 **1mk**

1g of H_2 will produce 40/12g of NH_3

4g of H_2 = 40/12 × 4g of NH_3

13.3g of NH_3 **1mk**

2.$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$ $\triangle H = -92KJmol^{-1}$

Answer: four volumes of the reactants give 2 volumes of product **1mk**

Increasing pressure will lead to more reactions of nitrogen and hydrogen.

Increasing pressure will lead to corresponding decrease in volume and increasing the number of effective collision.

Increasing temperature will also lead to more reactions of nitrogen and hydrogen and more effective collision. **1mk**

Increasing both pressure and temperature will lead to increase production of ammonia gas. **1mk**

3. Electrolysis of aqeous copper(II)tetraoxosulphate(VI) between copper electrodes.

$CuSO_4 \longrightarrow Cu^{2+} + SO_4^{2-}$

$H_2O \longrightarrow H^+ + OH^-$ **1mk**

At the Cathode: Cu^{2+} and H^+ move to the cathode, but Cu^{2+} requires less energy for discharge than H^+ and is discharged in preference to H^+ since it is below hydrogen in the electrochemical series.

$Cu + 2e^- \longrightarrow Cu$. Copper is deposited.

At the Anode: SO_4^{2-} and OH^- move to the anode. OH- requires less energy for discharge than SO_4^{2-}

$4OH^- \longrightarrow 2H_2O + O_2 + 4e^-$

Copper atoms at the anode ionise to copper ions that go into solution. **1mk**

$2Cu^{2+} \longrightarrow 2Cu^{2+} + 4e^-$. thus copper dissolves at the anode.

Hence, mass of copper at the anode reduced from 9.20g to 6.00g after the experiment.

Copper is deposited at the cathode,

Mass of Cu deposited

$Cu + 2e^- \longrightarrow Cu$ **1mk**

4 . $4P_{(s)} + 5O_2 \longrightarrow 2P_2O_{5(g)}$

$P = 0, O = 0 \longrightarrow 2((2\times X) + (-2\times 5)) = 0$ **1mk**

$= 2X + 10 = 0$

$2X = 10$

$X = 10/2$

$= 5$ **1mk**

Oxidation number of phosphorus increases from zero to 5 while that of oxygen decreases from zero to -2 **1mk**

5. Answer :

$3Cu_{(S)} + 8HNO_3 \longrightarrow 3Cu(NO_3)_{2(aq)} + 2NO_{(g)} + H_2O_{(g)}$

$3Cu - 6e^- \longrightarrow 3Cu^{2+}$

$8HNO_3 + 6e^- \longrightarrow 6NO_3^- + 4H_2O + 2NO$ **1mk**

Oxidation number of copper increases from o to +2 and it donates 2 electrons per atom to form copper (II) ions. The electrons are accepted by the acid which becomes partially reduced to nitrogen (II) oxide. **1mk**

Trioxonitrate (V)acid is an oxidising agent while cooper is a reducing agent. **1mk**

6 Answer:

Reactants collide but not all collision lead to the formation of the product. **1mk**

Collision that leads to the formation of product is referred to as effective collision. **1mk**

For effective collision to take place:

(i) Reactant particles must possess minimum amount of energy called activation energy

(ii) A reaction with low activation energy will take place spontaneously at room temperature while a reaction with high activation energy will take place only when energy is supplied. **1mk**

7 Answer:

$CuSO_4 \longrightarrow Cu^{2+} + SO_4^{2-}$

$H_2O \longrightarrow H^+ + OH^-$ **1mk**

At the anode: OH^- and SO_4^{2-} move to the anode. OH^- requires less energy for discharge than SO_4^{2-}

$4OH^- \longrightarrow 2H_2O + O_2 + 4e^-$

At the Cathode: Cu^{2+} and H^+ move to the cathode. Cu^{2+} requires less energy for discharge than H^+ since it is below hydrogen in the electrochemical series

$Cu^{2+} + 2e^- \longrightarrow Cu$ **1mk**

Cu^{2+} and OH^- are removed from the solution. Cu is deposited on the cathode and O_2 is liberated from the anode. H_2 and SO_4^{2-} are not discharged. The solution changes to acid **1mk**

(8) How many moles are there in 20g of $CaCO_3$?

Answer: number of moles = Mass given÷ Relative atomic mass **1mk**

Relative atomic mass of $CaCO_3$ = (40+ 12+(16×3) = 100 **1m**k

moles of in 20g of $CaCO_3$ = 20÷100

0.2mole **1mk**

APPENDIX VII

ANSWERS TO CRITICAL THINKING TEST

(1) D (2) D (3) C (4) C (5) D

APPENDIX VIII

OPERATIONAL GUIDE FOR TEACHER DEMONSTRATION (OGTD)

Instruction

This operational guide is teacher-centered demonstration in an inquiry-based teaching. It is to be used by the teacher in engaging students in control group C in practical activities. The teacher carries out the investigations while the students watch critically and pay attention to the discussions on the investigations. Students are allowed to ask questions on the outcomes of the investigations, principles and concepts underlying the investigations from the teachers.

Redox reaction

Activity 1: Redox reaction between Zinc and Copper II tetraoxosulphate VI solution

The teacher measures 20cm^3 of 0.1 molar (25.0g of $CuSO_4.5H_2O$ per dm^3) of $CuSO_4$. Immerses a Zinc granule into the solution:

(a) Explains the reaction with the students in terms of redox reaction.

(b) Write ionic half equations for the reaction]

(c) Explains what happens if a strip of Iron is immersed in the solution of Copper (II) tetraoxosulphate (VI). Give reason(s).

Materials needed: 100cm^3 beakers, Zinc granule, Copper (II) tetraoxosulphate (VI) salt, measuring cylinder.

Activity 2: Redox reaction between acidified Potassium tetraoxomagnate (VII) and Potassium Iodide

The teacher measures 1cm^3 of 0.2M potassium tetraoxomanganate (VII) solution, puts little drops of 1M solution of tetraoxosulphate (VI) acid, and then adds 2cm^3 of 0.5 molar of potassium Iodide. Inserts starch paper into the solution.

(a) Explains the findings of the reactions.

(b) Writes balanced ionic equation for the reaction, shows all the steps involved.

Material needed: Test tubes, Potassium tetraoxomangate (VII) solution, dilute tetraoxosulphate (VI) avid, H_2SO_4, potassium Iodide.

Chemical Kinetics

Activity 3: Reaction between 2.0M HCl and sodium trioxothiosulphate (VI) $Na_2S_2O_3$ solution

The teacher measures 10cm^3 of the 0.2M $Na_2S_2O_3$ solution into a 100cm^3 beaker by the use of a measuring cylinder. Adds 10cm^3 of 2M HCl from another measuring cylinder, into the solution, and starts the stop-watch. Swirls the mixture briefly, and then, placed the beaker on a filter paper with the black mark X on it. Looks through the mixture from above, and stops the watch and notes the time taken for the X mark to disappear.

(a) Records the time taken in seconds for the reaction to be completed on the chalkboard

(b) Records the colour observed when reaction is completed

(c) Estimates the rate of reaction in volume (cm^3) per second

(d) Prepares different concentrations of sodium $Na_2S_2O_3$ solutions by diluting the original solution with distilled water as follows:

Experiment Number	1	2	3	4
Volume of $Na_2S_2O_3$ (cm^3)	8.0	6.0	4.0	2.0
Volume of distilled water (cm^3)	2.0	4.0	6.0	8.0
Time Taken (Second)				

Repeat the procedure above by adding $10.0cm^3$ of the 2M HCl each to each of the diluted solutions of $Na_2S_2O_3$

(1) Record the time taken for the reaction to complete in each case.

(2) Explains the findings with reason(s)

(3) Demonstrates how to plot a graph of the volume of $Na_2S_2O_3$ used against the time taken in seconds

Materials needed: $100cm^3$ beaker, filter paper with X mark on it, 2 measuring cylinders, 0.2M $Na_2S_2O_3$ (50.0g $Na_2S_2O_3.5H_2O$ per dm^3) and 2M HCl ($200cm^3$ Con. HCl per dm^3).

Activity 4: Reaction between a metal and an acid

(a) The teacher measures $20cm^3$ of 2 molar HCl into $100cm^3$ beakers; beakers A and B. Drops a piece of magnesium wire (2cm long) into the acid in beaker A and to beaker B, one heaped spatula (0.30g) of magnesium powder. Starts a stop watch and stops the stop watch as soon as effervescence ceases for both reactions.

(1) Record the time taken in each case.

Experiment	Time Take
A	
B	

(2) Explains the results using collision theory

(3) Write equation for the reaction.

(b) Repeat the experiment by using $20cm^3$ of 2 molar HCl and 2cm – long of magnesium wire at a temperature of about 45^0C. The temperature is obtained by warming and then cooling it to 45^0C, using a thermometer. Then add 2cm long magnesium ribbon and then

(1) Record the time taken for effervescence to occur

(2) Explains the findings with the students

(c) Repeat the experimental procedure by adding $2cm^3$ of 0.5M manganese (II) tetraoxosulphate (VI), $MnSo_4$ solution to $20cm^3$ of 2M HCl before dropping the 2cm long magnesium ribbon into the mixture.

(1) Record the time taken for effervescence to occur

(2) Explains the findings

(3) Writes equation for the reaction.

Materials needed: Stop watches, Magnesium powder, Magnesium ribbons, thermometers, 0.5M manganese (II) tetraoxosulphate (VI), $MnSO_4$, solution, 2M hydrochloric acid, $100cm^3$ beakers, spatula.

Electrolysis

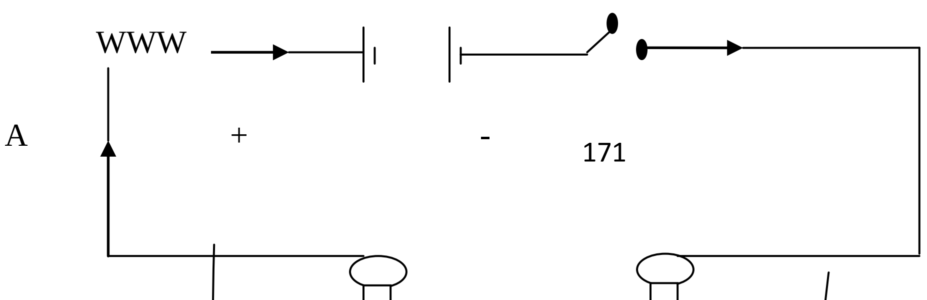
Activity 5: Investigation of the movement of ion during electrolysis using a filter paper

(a) The teacher places the moisten one end of the paper with silver trioxonitrate (V), $AgNO_3$, solution and at the other end with potassium tetraoxochromate (VI), K_2CrO_4, solution. Places the wet filter paper on top of a microscopic slide and secures it at both ends with crocodile clips to a battery of about 20 volts.

1. Asks students to observe what happens at the center line of the filter paper
2. Explains the observation in terms of electron movement.

Activity 6: Verification of Faraday's First law of electrolysis using Copper (II) tetraoxosulphate VI solution with copper electrodes

The teacher sets up an electrolytic cell as shown



The magnitude of the current is measured by the ammeter, while the rheostat is used to adjust the current to the required magnitude. The mass of the copper cathode is first determined. The circuit is connected and a current of 0.2A is passed for 15 minutes. Switches off the current,remove the copper cathode and wash it carefully in distilled water and allow to dry and then weigh.

(1) Explains the findings with students. Repeats this procedure, using different time intervals (e.g. 20, 25, 30 minutes)

(2) Weighs the cathode again and determine the gain in mass at the different time intervals

Time Interval (Minutes)	Gain in Mass of the cathode
15	
20	
25	
30	

(3) Demonstrates how to plot (sketch) a graph of the gain in mass against time (at different intervals)

(4) Repeats the experiment, but this time, passes current of different magnitude (0.25A, 0.30A, 0.35A) for a fixed period of time

(5) Explains the findings, determines the gain in mass and demonstrates how to plot (sketch) a graph of gain in mass against the magnitude of the current.

Quantity of Current Passed (Amphere)	Gain in Mass
0.25	
0.30	
0.35	

(6) Writes the cathodic and anodic half reaction for reactions.

Materials needed: Copper electrodes, copper (II) tetraoxosulphate (VI) solution, direct current supply (battery) Crocodile clips, electric wire, copper electrodes, 500cm^3 of beakers, Ammeter, rheostats, paper, graph sheet.

Chemical Equilibrium

Activity 7: Reaction between Iron III chloride and Ammonium thiocyanate solutions to investigate the effect of concentration as equilibrium mixture

(a) The teacher measures 2cm^3 of 0.05M of $FeCl_3$ solution into 2cm^3 of NH_4SCN solution and Record the observation on the chalkboard.

(b) Measures 50cm^3 of distilled water into 100cm^3 beaker, add 2cm^3 of 0.05M $FeCl_3$ and 2cm^3 of NH_4SCN to the water to obtain a light red solution. The teacher divides the solution in the beaker into four test-tubes so that each test-tube is about half full.

(1) To the first test tube, add 2cm^3 of water as reference. Record your observation.

(2) To the second test-tube add 2cm^3 of the 0.05 molar NH_4SCN (or a small crystal of NH_4SCN). Record your observation

(3) To the third, add 2cm^3 of the 0.05 molar $FeCl_3$. Record your observation

(4) To the fourth test tube, add 2cm^3 of the 0.05 molar NH_4Cl solution. Records your observation

(c) Explains the observation using Le-Chatelier principle

(d) Writes a balanced reversible chemical equation for the reactions in the fourth test tube

(e) Writes equilibrium constant for the reaction in the fourth test tube

Materials needed: 100cm^3 beakers, test tubes measuring cylinders, 0.05M NH_4SCN (4.0g per dm^3), 0.05M NH_4Cl (3.0g per dm^3).

Activity 8: The effect of temperature changes on a equilibrium mixture of Nitrogen (IV) oxide, NO_2 and dinitrogen (IV) oxide, N_2O_4

The teacher places a full spatula of lead (II) trioxonitrate (V) crystals in a test tube and heat strongly. When the gas starts to evolve, connects a gas syringe with rubber tubing to the test tube. Slowly withdraws the plunger to collect about $20cm^3$ of the gas. The teacher allows the gas in the syringe to cool down to room temperature. Note its colour.

(a) Sets up two beakers; one containing ice water at 0^0C and another containing hot water at 100^0C.

(b) Immerses the syringe containing the gas collected in into the ice water for a few minutes. Notes the rapid change in colour. Next, plunges the gas syringe containing gas into the hot water and observes what happens.

(c) Explain the observations with the students

(d) Writes the balanced reversible chemical reaction for the gas

(e) Writes equilibrium constant for the reversible of the nitrogen (IV) oxide and nitrogen.

Material needed: Lead (II) trioxonitrate (V), ice blocks, $20cm^3$ of gas syringes and plunger $250cm^3$ beakers, boiling test tubes, retort stand, Bunsen burner, rubber corks, rubber tubing.

APPENDIX IX

Rating scale for Teachers Competency

S/N	Statement	Yes	No
1	Does the teacher possess adequate knowledge and capability to handle the teaching strategy		
2	Does the teacher adequately understood the teaching strategy		
3	Does the teacher have adequate knowledge of the procedural steps involved in the operational guide		
4	Does the teacher have adequate knowledge of Chemistry		
5	Does the teacher have interest in engaging the students using the strategy?		

APPENDIX X

Review of WAEC (May/June) chief Examiners' Reports on Students' Conceptions on Electrolysis, Chemical Kinetics, Oxidation-Reduction and Chemical Equilibrium from 2006-2013

The chief examiners' general comments and specific reports on students' conceptions on the topics are presented as follows:

Year 2006

In the year 2006, the WAEC chief examiners' reported that candidates' performance was poor when compared with those of previous years. The candidates' weaknesses include:

- Inadequate practical exposure;
- Poor quantitative skills
- Inability to draw workable well-labelled diagram
- Poor level of communication skill

Redox Reactions

In question 4(a)(i) and (ii), candidates were unable to write balance half equations for the oxidation and reduction reaction for the reaction represented by the following equation:

$$MnO_4^- + I^- + H^+ \longrightarrow I_2 + H_2O + Mn^{2+}$$

Chemical Kinetics

Question 2(d) dealt with the use of kinetic theory to explain how the rate of formation of $HCl_{(g)}$ in the reaction presented: $H_{2(g)} + Cl_{2(g)} \longrightarrow 2HCl_{(g)}$ would be affected by increase in temperature and decrease in pressure. Most candidates lost marks because they left out the key word "effective" in their explanations. Also, some of them confused the reaction with equilibrium reactions since the number of moles of the reactants equals that of the products.

The expected answers to the question are:

1. Increase in temperature increases the kinetic energy of the particles/molecules resulting in increase in collision leading to increase in effective collision hence, the rate of reaction increases.
2. Decrease in pressure leads to an increase in volume, particles are further apart resulting in fewer effective collisions hence, rate of reactions decreases.

Also, for chemical kinetics, in question 8(a)(i), the candidates were asked to draw the energy profile in this chemical reaction:

$$H_{2(g)} + I_{2(g)} \longrightarrow 2HI \qquad \Delta H = 13.KJmol^{-1}$$

Some of the candidates were able to draw correctly the required energy profile diagram. However, some of them could not correctly label the axes hence, lost some marks.

In question 8(a) (ii), candidates could not determine the rate of the reaction if the concentration HI of increase from 0 to 0.001 $moldm^{-3}$ in 50 seconds.

Electrolysis

Question 4 was n electrolysis and redox reaction. The question was attempted by a good number of the candidates and the performance was fair. In question 4(a)(i), the candidates were able to calculate the mas of the cathode after the electrolysis of a solution of $CuSO_4$ between pure copper electrodes.

For question 4(a)(ii), candidates could not write the anodic and cathodic equations for the electrolysis of the solution $CuSO_4$. Many candidates correctly state that the colour of the solution would not change during electrolysis in question 4(a)(iii). However, some of them could not give a reason for that statement. The expected response was that there would be no change in the colour of the solution because copper ions discharged at the cathode are replaced by copper ions produced at the anode.

In question 4(a)(iv), the candidates were asked to determine the value of Faraday if the electrolysis was out for 1hour 20minutes with current of 2.0amperes. Most candidates shield away from the question.

Year 2007

In the year 2007, the reports of the WAEC examinations showed no significant improvement in the performance of candidates when compared with those of previous years. The candidates showed mark improvement in their understanding of energy profile diagram and electrolysis. However, the candidates' weaknesses include:

- Lack of understanding of the demand of the questions;
- Lack of good communication skills
- Lack of good mathematical skills
- Inability to correctly write balanced chemical equations;
- Inability to answer questions based on practical applications;
- Inability to relate concepts in chemistry to everyday life;
- Inadequate practical exposure.

Redox Reactions

Question 2 was on redox reactions. The question was popular among the candidates and the performance in it was fair. In question 2(a)(i) and (ii), candidates correctly defined oxidation as the process of electron loss and reduction in the process of electron gain. A few of the candidates however, lost marks because the defined the terms with respect to oxygen and hydrogen.

Also, in question 2(b)(i) I and II, majority of the candidates were able to correctly determine the oxidation state of Phosphorus in $POCl_3$ and PH_3. However, some of them lost marks because they failed to assign the sign (+).

Chemical Kinetics

In question 4(c)(i) and (ii), candidates correctly named the reaction shown:

$$Mg + 2HCl_{(aq)} \longrightarrow MgCl_2$$

as displacement redox reaction and gave two ways by which the reaction could be made faster as follows:

- Use Mg powder (increase surface area of Mg);
- Use HCl of higher concentration (higher concentration of HCl);
- Increase temperature of the reaction mixture in the reaction.

Also, the candidates were also able to calculate the volume of hydrogen that would be produced from the given mass of Magnesium according to the reaction equation in question 4(c)(iii).

Question 6(a) was on chemical kinetics. In 6(a)(i), some candidates correctly drew and labelled the energy profile diagram of an endothermic reaction indicating the activation energy and heat change, ΔH. However, some of the candidates wrongly drew the energy profile diagram of an exothermic reaction and hence, lost the marks. Also in 6(a)(ii), candidates correctly explained the addition of a catalyst increases the rate of a reaction by providing alternative pathway with lower activation energy and increase in temperature increases the rate of reaction because there will be more effective collisions.

It was also reported that a few of the candidates wrongly drew the energy profile diagram of an exothermic reaction and hence, lost the marks.

Electrolysis

In question 3(d)(i) and (ii), candidates correctly defined an electrolyte and electrolysis as a compound which in molten or aqueous solution will conduct electricity (and be decomposed by it) and the decomposition of an electrolyte by the passage of an electric current. Also, in question 4(e), candidates correctly mentioned the substances discharged at each electrode when dilute NaCl is electrolysed, using graphite electrodes as;

Cathode – Hydrogen

Anode – Oxygen

The candidates were able to explain why aqueous NaCl conducts electricity but solid NaCl would not as:

In the liquid state, the Na and Cl ions are mobile;

In the solid state, the ions are in fixed positions and cannot conduct electricity.

Year 2008

For year 2008 WAEC examinations, the performances of the candidates were better than that of May/June 2007 WASSCE. The candidates showed remarkable improvements in the following areas:

- Definition of some chemistry terms;

- Nuclear chemistry
- Stoichiometry and solutions
- Mole concepts
- Water and solutions
- Acids, Bases and Salts
- Organic chemistry

However, the candidates' weaknesses include:

- Poor communication skills
- Lack of understanding of the collision theory
- Inability to write a balanced equation to show that carbon is a reducing agent.

Redox reactions

Question 2(a)(i) was on redox reactions. The candidates correctly defined oxidizing agents and reducing agent in term of electron transfer as follows:

I. Oxidizing agent is a substance which accept electrons/ is an electron acceptor.

II. Reducing agent is a substance which denotes electrons/is an electron donor.

In question 2(a)(ii) and (iii), most of the candidates could neither write a balanced equation to show that carbon is a reducing agent nor state the change in oxidation number of the species that reacted with carbon.

Chemical kinetics

Question 8(d) dealt with chemical kinetics. The question was attempted by most candidates

For the question 8(d)(i), most candidates did not know that activated complex is the intermediate (complex) that reactants must attain in order to form a product or a temporary species formed by reactant molecules as a result of collision before the products are formed instead, the candidates gave the definition of activation energy.

Also for question 8(d)(ii), most candidates could not state one reason why collision may not produce a chemical reaction. The candidates did not know that if the energy of the colliding particles is less than the activation energy or the reactants are not properly aligned, chemical reaction may not occur in spite of collision. In question 8(d)(iii), most of the candidates drew the energy profile diagram for the endothermic reaction but most of them did not indicate the enthalpy of reaction.

Year 2009

The chief examiners' report for year 2009 WASSCE indicated that the performance of the candidates was poorer than that of the May/June 2008 WASSCE. The candidates' weaknesses associated with the performance include:

- ✓ Poor Mathematical skills
- ✓ Lack of understanding of the demand of the questions;
- ✓ Non attachment of magnitude (Sign/Charges) to oxidation number
- ✓ Inability to relate concepts in chemistry to everyday life.

Redox Reactions

Questions 1(c)(i), and (d) were on redox reactions. In question c (i) and (ii), the candidates correctly determined the oxidation number of Mn and stated one laboratory use of each of the given compounds. However, some of the candidates lost marks because they did not assign magnitude (sign) to the oxidation number. Also, in 1(d) the candidates knew that oxidation is a process of electron loss while reduction is a process of electron gain and that a species can only be oxidized if there is another species that would accept the donated electrons

In question 1(e), the candidates wrote the balanced ionic half equation a follows:

$$Fe_{(s)} \longrightarrow Fe^{2+}_{(aq)} + 2e^-$$

$$Ag^{2+}_{(aq)} + e^- \longrightarrow Ag_{(s)}$$

Also, most of the candidates knew that F was oxidized, Ag^+ was reduced and that the change in oxidation number of silver was +1 to 0.

Electrolysis

Question 7(e) was on electrolysis. Most candidates stated the ions present in the concentrated solution of sodium chloride as Na^+Cl^- and H^+ OH^-, named the products at the anode and cathode as chlorine and hydrogen respectively and gave the product of the electrolysis as $NaOH_{(aq)}$.

Year 2010

The reports of the chief examiners on the WAEC examination in the year 2010, the performance of the candidates was better than that of May/June 2009 WASSCE.

The candidates showed commendable improvements in their ability to recall simple facts, definitions and statement of the laws. The performance of candidates was affected by the following exhibited weaknesses:

- Lack of understanding of the demands of the questions.
- Rampant spelling mistakes and poor communication;
- Poor mathematical skill/manipulative skills;

- Inability to explain why sugar and common salt do not conduct electricity in the solid state;
- Poor knowledge of concepts of electrolysis;
- Inability to balance chemical equations

Electrolysis

Question 2(b)(ii) dealt with electrolysis. The candidates could not explain why sugar and common salt do not conduct electricity in solid state. The expected answer from the candidates was that sugar is covalent while common salt (NaCl) is electrovalent/ionic. Electrical conductivity in compound depends on presence of mobile ions. Sugar does not conduct electricity because it does not contain ions (they are molecules) while solid common salt does not conduct electricity because its ion are not mobile. Question 8(b) also was on electrolysis. For the question 8b (i) and (ii), the candidates could not write balanced equation for the oxidation half reaction, reduction half reaction and overall reaction. The calculation of the volume of gas liberated at the anode at standard temperature and pressure from the electrolysis of dilute H_2SO_4, when a current of 1.24A was passed for 40 minutes was very difficult for the candidate to determine. Question 8 was reported to be the least popular among the candidates and the performance was poor.

Year 2011

The chief examiners' report on the May/June WAEC examinations in 2010 on the performances of the chemistry candidates was that the candidates' performance was better compare to that of May/June 2010 WASSCE. The candidates' performance was affected by some of the following weaknesses:

- Poor computational skill;

- Poor comprehension on application of principles;
- Lack of adequate knowledge of some concepts;
- Usage of unconventional symbols of elements such as AL instead of Al; fe instead of Fe;
- Inadequate understanding of activation energy and activation complex;
- Poor study habit;
- Inability to balance chemical equations.

Redox Reactions

Question 1(b)(i), (ii) (iii); 3d(i) and 7b(i), (ii), (iii), e(i), (ii) were on redox equations.

Most candidates that responded to Question 1b(i) failed to realise the role of salt bridge in an electrochemical cells, rather, they saw the role as that of "competing the circuit". This type of ions that migrates to the cathode and why it does so also posed a challenge to the candidates in question in question 1b (ii). Most of the candidates could not write the overall cell reaction and therefore could not determine the standard cell potential although, a few of them were able to calculate this correctly in question 1b(ii) and (iii). Many candidates were able to determine the oxidation state of Al in $[Al\ (H_2O)\ _6]^{3-}$ and H in NaH. For question 7b(i), only few candidates were able to write a balanced equation to illustrate the reducing properties of NH_3 in its reaction with CuO. Few candidates were able to state that heating ammonium dioxonitrate (III) could be explosive but could not explain why for question 7b(ii). Most candidates strongly gave the use of nitrogen in question 7b(iii) as in the manufacture of fertilizers (which is not a direct use). Question 7e where candidates were to determine the oxidation states of chlorine and vanadium in Cl_2, ClO_3– and V_2O_5 were poorly attempted by the responding candidates.

Electrolysis

Question 1 b (iii) was on electrolysis. Many of the candidates could not calculate the number of moles of electrons and the amount of coulombs of charges. The expected answer is as shown:

I mole of electron = 96500C

0.003 moles of electron = 96500 x 0.003 = 289.5

= 2.895×10^2C

Chemical Kinetics

Questions 1c and 8a were on chemical kinetics. Many candidates were able to define activation energy and exothermic reaction but could not give the significance of activated complex in a chemical reaction nor give an example of the endothermic process. For question 8a, few candidates would not draw the graph of exothermic reaction. Few of the candidates did not label the axes and also failed to name the reactions and products of the energy profile. Many of the candidates got the calculation aspect of the question but failed to indicate the unit.

Year 2012

The performance of the chemistry candidates in the year 2012 WAEC/SSCE on chemistry was poor compared to May/June 2011 WASSCE. The chief examiners' reported the following weaknesses associated with candidates' performance in the subject include:

- Lack of understanding of the demand of the question;
- Poor presentation/ communication skills
- Inability to write chemical formulae accurately and balance chemical equations;
- Poor knowledge of electrochemical cells and its related calculations

- Poor knowledge of redox reactions

Redox Reactions

Question 7 was centred on redox reactions. The question was attempted by majority of the candidates and the performance was fair. In 7a (i), (ii), and (iii), most candidates correctly defined standard electrode potential and gave uses of the values of standard potential. However, some of the candidates could not properly define standard electrode potential. In question 7a (iv), most of the candidates could not draw and label correctly electrochemical cell. Only a few candidates could define oxidation in terms of electron transfer in question in question 7b (ii) and (iii). Also, majority of the candidates could not balance redox reaction. The expected half reactions for balance of the redox reaction are:

$$2H^- \longrightarrow I_2 + 2e^-$$

$$5e^- + 8H^+ + MnO_4^- \longrightarrow Mn^{2+} + 4H_2O$$

$$\text{Balancing } 10I^- \longrightarrow 5I_2 + 10e^-$$

$$10e^- + 16H^+ + 2MnO_4 \longrightarrow Mn^{2+} + 8H_2O$$

$$10e^- + 16H^+ + 2MnO_4 \longrightarrow 5I_2 + Mn^{2+} + 8H_2O$$

Chemical Equilibrium

Question 2b(i) and 3b (i), (ii) and (iii) were on equilibrium. Most of the candidates correctly state Le Chatelier's principle in question 2b (i). Majority of the candidates were not able to respond appropriately to answer the questions. Most candidates lost marks by not further stating the effect of increase in concentration of B, decrease in pressure of the system and adding of catalyst into the chemical reaction as shown:

$$A_{2(g)} + 3B_{2(g)} \rightleftharpoons 2AB_{3(g)}; \quad \Delta H = xKJmol^{-1}$$

The candidates were expected to state that:

Equilibrium position shifts to the right and more of AB_2/ decrease in concentration of A_2

Equilibrium shifts to the left and more of A_2 and B_2 formed / decrease in concentration of AB_3

Catalyst has no effect on the reaction. Catalyst affects both the forward and backward reactions equally.

Year 2013

The performance of the candidates of May/June 2013 was reported by chief examiners as better than that of May/June 2012 WASSCE. However, the weaknesses associated with the candidates' performance include:

- Poor communication skills;
- Poor study habits;
- Lack of understanding of the demands of the questions;
- Poor mathematical skills in calculation
- Inability to balance chemical equations
- Inability to properly define terms such as standards electrode potentials
- Poor knowledge of concept of electrolysis

Redox Reaction

Question 3a(i) and (iii) were on redox reactions. Majority of the candidates could not properly define standard electrode potential. The candidates could not also state the functions a salt bridge. The expected answers include:

Standard electrode potential is the measure of the tendency of an elementto form ions in solution relative to the tendency of hydrogen atoms to form ions at standard conditions. Or is the potential difference that exists between an electrode and the hydrogen electrode under standard conditions of 1 $moldm^{-3}$ concentration at 298k and 1 atm. The functions of salt bridge include:

- Allows electrical contact between the two solutions/ complete the electric circuit
- Maintain electrical neutrality in each half cell/ allows ions flow in and out of the cell

Electrolysis

Some of the candidates were able to state factors affecting the discharge of ion during the electrolysis in question 3a (ii). For question 3b, majority of the candidates could not give all the ions present in $CuSO_{4(aq)}$ thereby leading to loss of some marks. However, the candidates' explanation of the ionization of $CuSO_4$ was fair. The expected ions in $CuSO_{4(aq)}$ are Cu^{2+} , SO_4^{2-}, H^+/H_3O^+, OH^-. Cu^{2+} and H^+ migrate to cathode. Cu^{2+} is discharged/Cu metal deposited /Cu cathode increases in mass. Copper anode dissolves/ionizes/decreases in size to give Cu^{2+}. Solution remains blue concentration of Cu^{2+} ions in constant. Majority of the candidates solved the calculation in question 3c, on the electrolysis correctly

Chemical Equilibrium

Question 7e was on chemical equilibrium where the candidates were to list two factors that would increase the yield of $NH_{3(g)}$ in the reaction shown:

$$N_2 + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}; \Delta H = -92.37kJ$$

The question was fairly attempted by majority of the candidates. The expected answers to the question were:

- Increase in pressure of the system/ decrease in volume of the system
- Decrease in temperature of the system
- Removal of ammonia/ product from the system

Year 2015

The performance of the candidates of May/June 2015 was reported by chief examiners as better than that of May/June 2014 WASSCE. However, the weaknesses associated with the candidates' performance include:

- Non-adherence to rubrics;
- Inability to balance chemical equations, especially redox reactions
- Poor knowledge of quantitative calculations;
- Inability to differentiate between raw materials and primary products;
- Inability of candidates to respond to questions that required explanations.

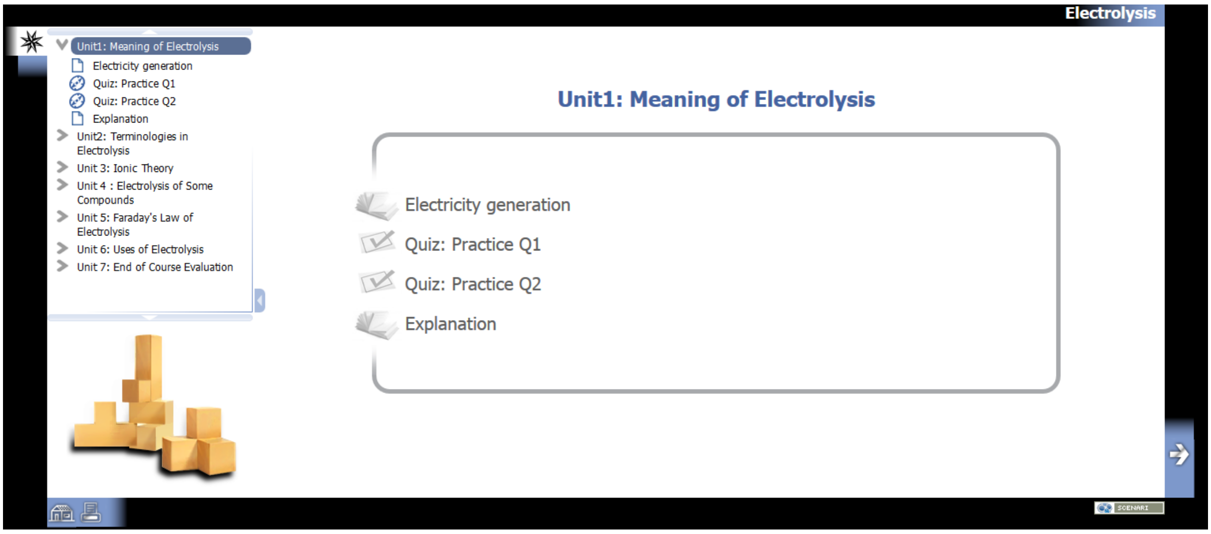
Electrolysis

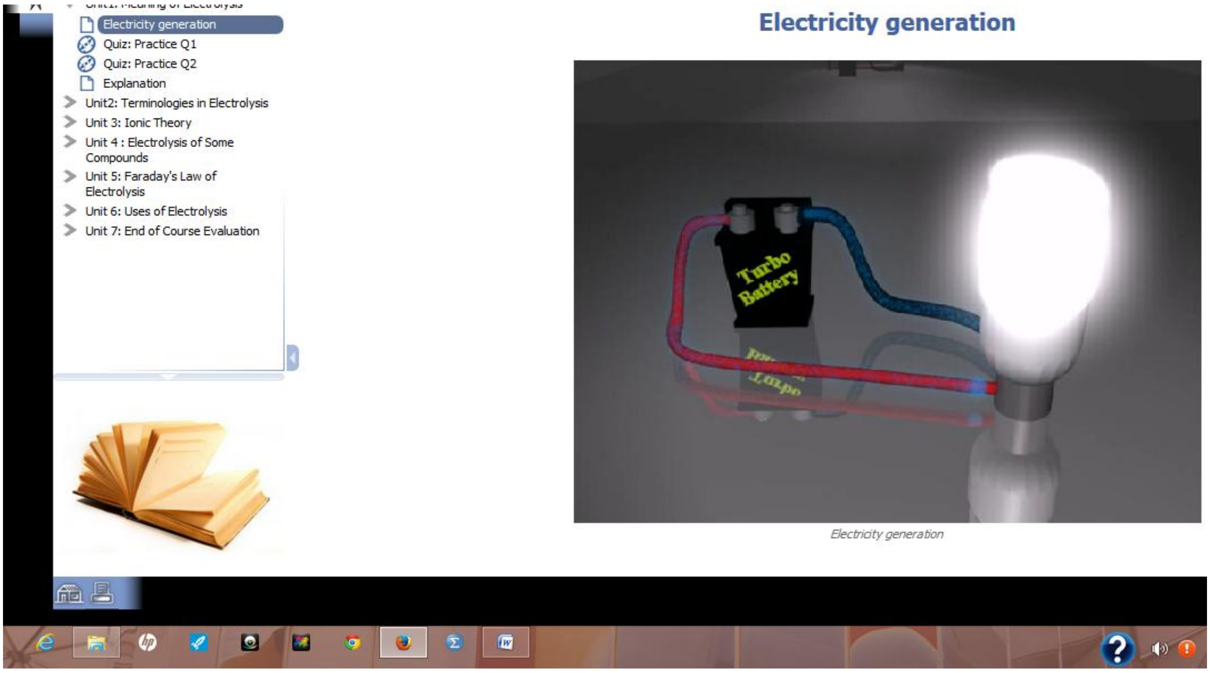
This question was unpopular among the candidates. Few candidates attempted this question and the performance was poor. Majority of the candidates could not correctly defined electrochemical cell. They confused with electrolytic cell. In part (b), most candidates could not give any correct reason, why cryolite is added to the electrolyte. In part (d), some candidates could not state what would be observed when chlorine gas is bubbled through aqueous NaCl.

APPENDIX XI:

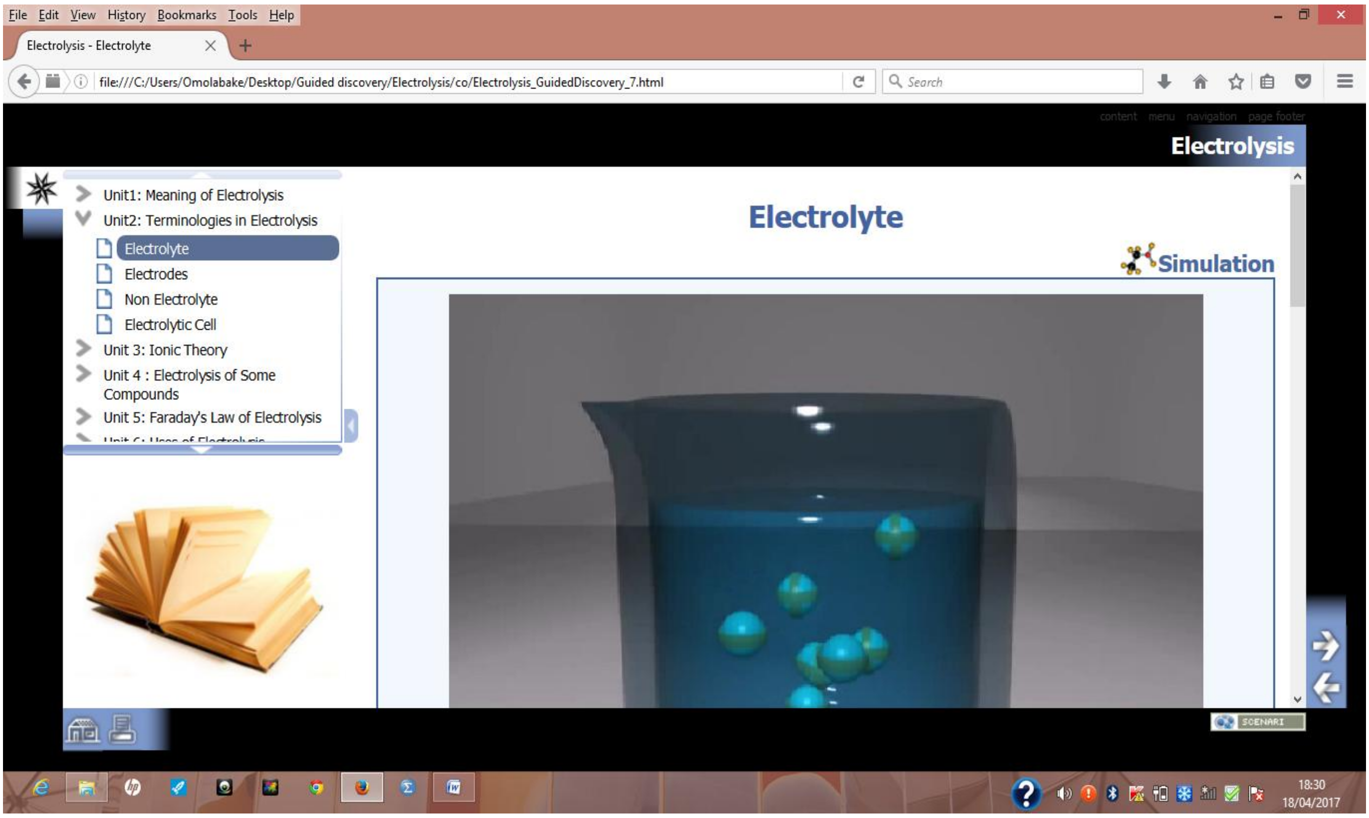
SELECTED FRAME FROM THE INTERACTIVE TEACHING PACKAGES

Login Interface





Selected Activity Interface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Electrolysis - Electrolyte
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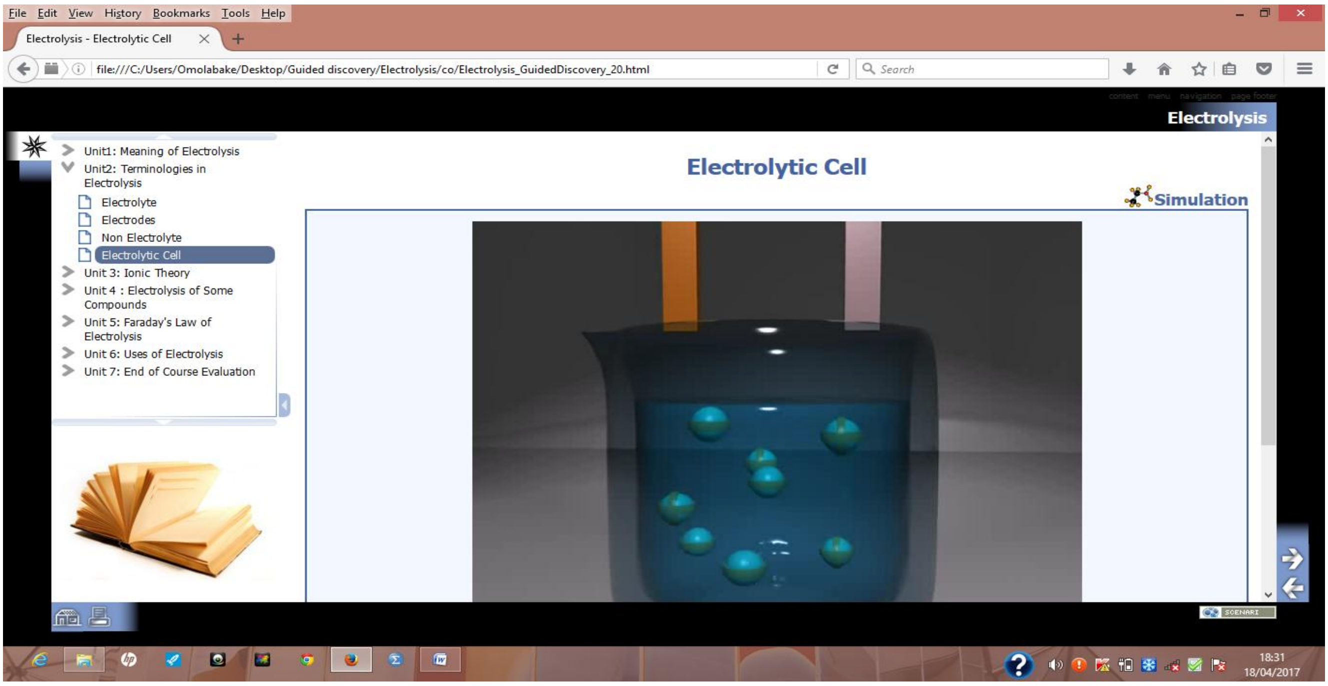
Search
Electrolysis
Unit1: Meaning of Electrolysis
Unit2: Terminologies in Electrolysis
Electrolyte
Electrodes
Non Electrolyte
Electrolytic Cell
Unit 3: Ionic Theory
Unit 4 : Electrolysis of Some Compounds
Unit 5: Faraday's Law of Electrolysis
Electrolyte
Simulation
18:30
18/04/2017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Electrolysis - Electrolytic Cell
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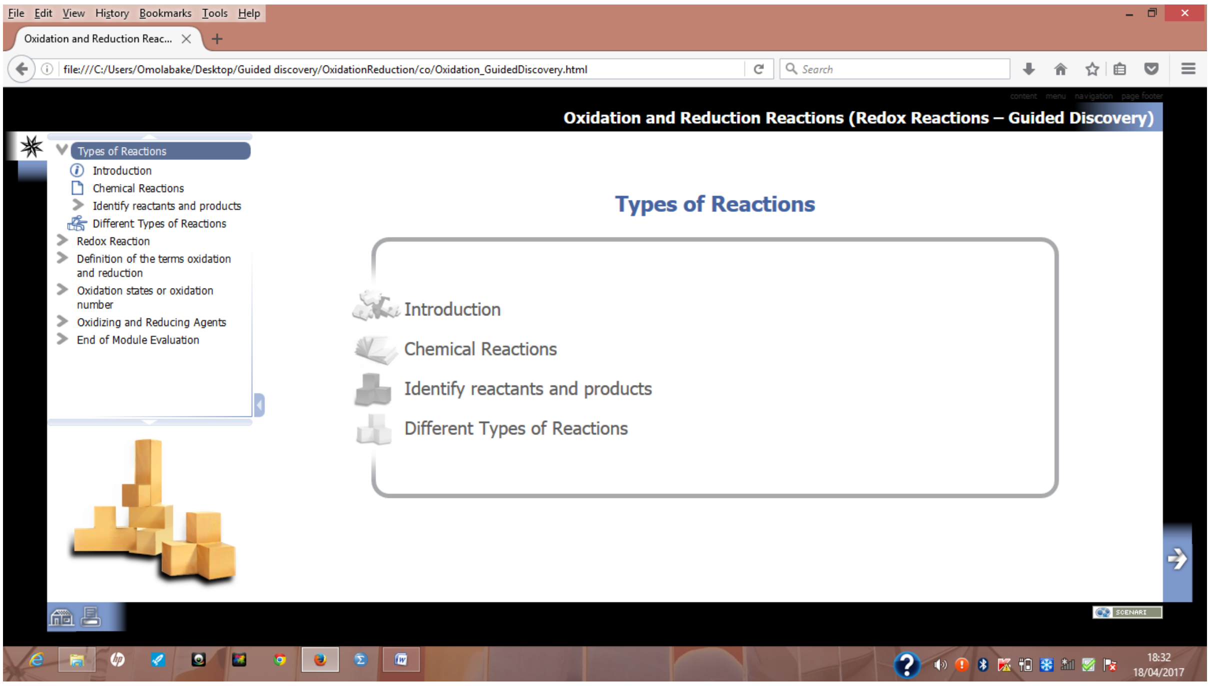
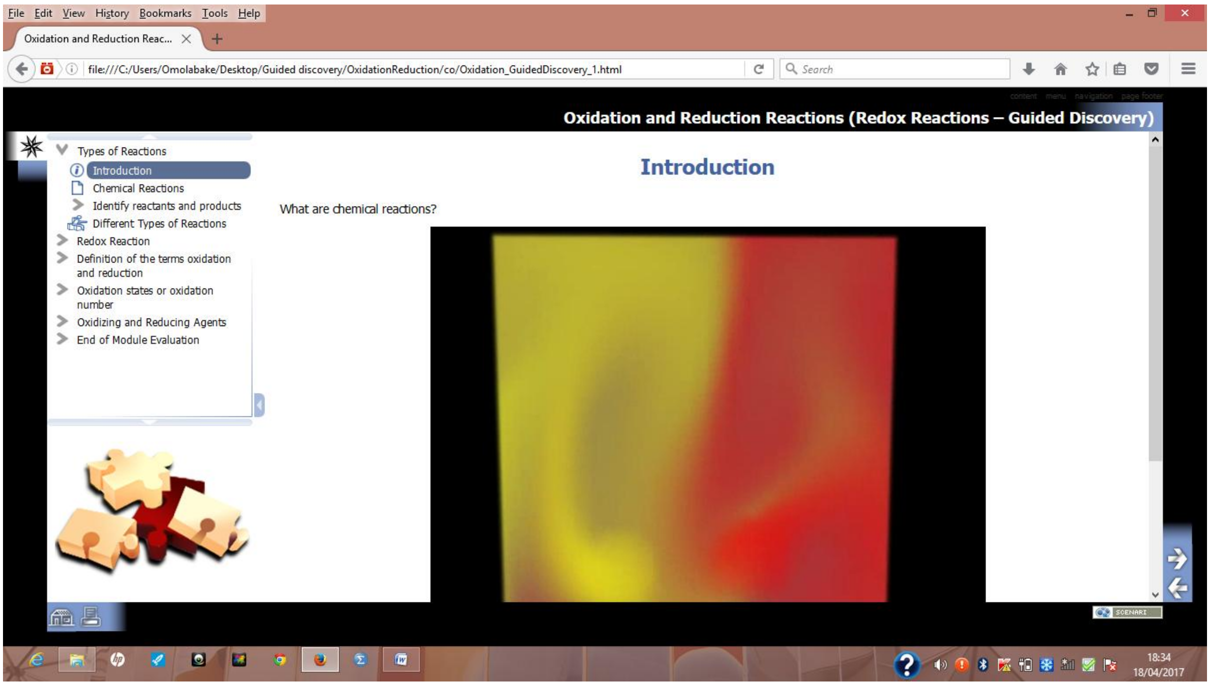
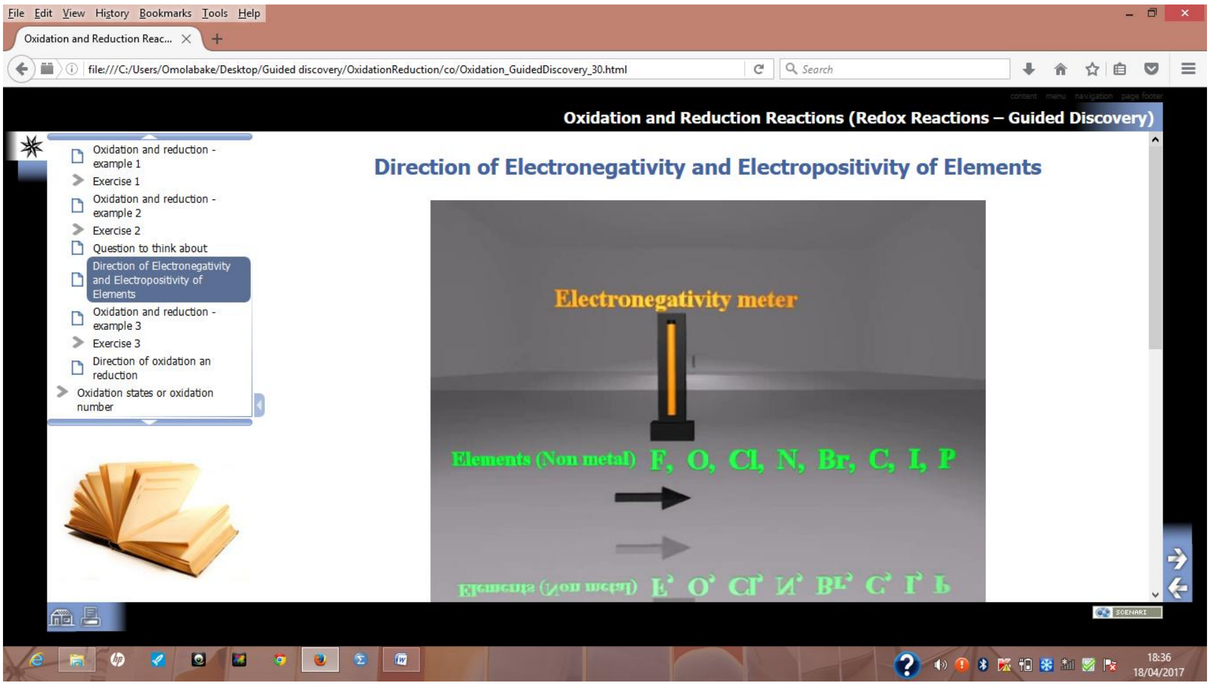
Search
Electrolysis
Unit1: Meaning of Electrolysis
Unit2: Terminologies in Electrolysis
Electrolyte
Electrodes
Non Electrolyte
Electrolytic Cell
Unit 3: Ionic Theory
Unit 4 : Electrolysis of Some Compounds
Unit 5: Faraday's Law of Electrolysis
Unit 6: Uses of Electrolysis
Unit 7: End of Course Evaluation
Electrolytic Cell
Simulation
18:31
18/04/2017

Login Interface



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Oxidation and Reduction Reac...
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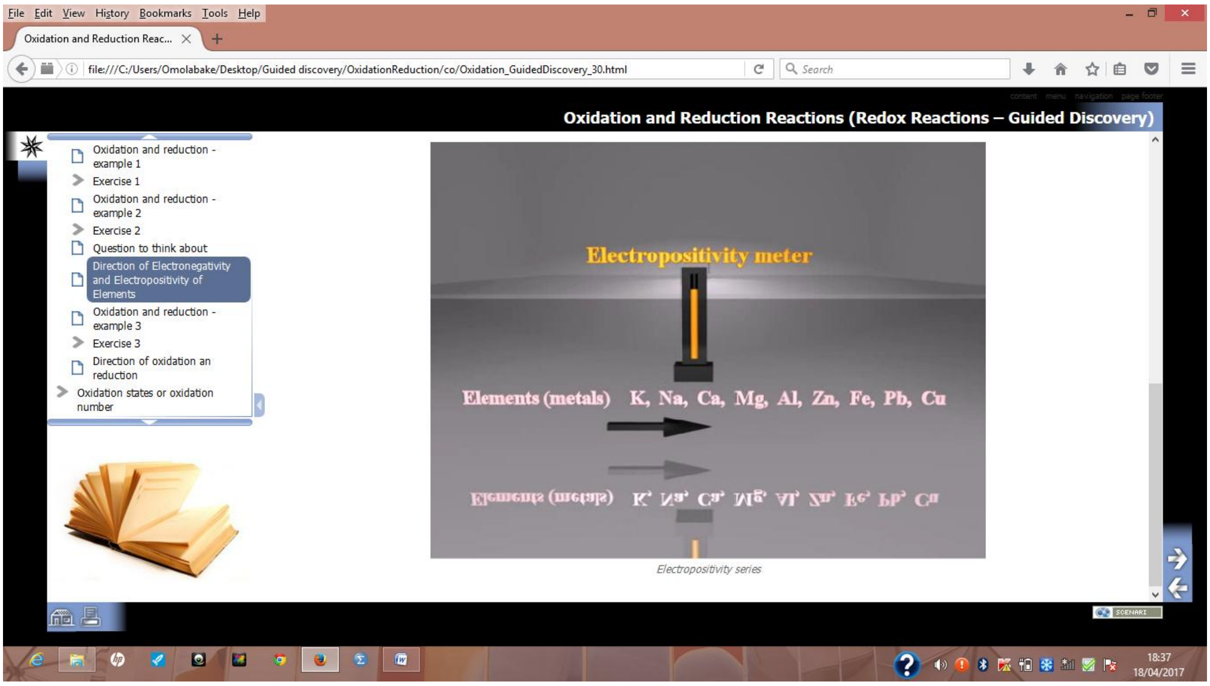
Oxidation and Reduction Reactions (Redox Reactions – Guided Discovery)
Oxidation and reduction - example 1
Exercise 1
Oxidation and reduction - example 2
Exercise 2
Question to think about
Direction of Electronegativity and Electropositivity of Elements
Oxidation and reduction - example 3
Exercise 3
Direction of oxidation an reduction
Oxidation states or oxidation number
Direction of Electronegativity and Electropositivity of Elements
Electronegativity meter
Elements (Non metal) F, O, Cl, N, Br, C, I, P
18:36
18/04/2017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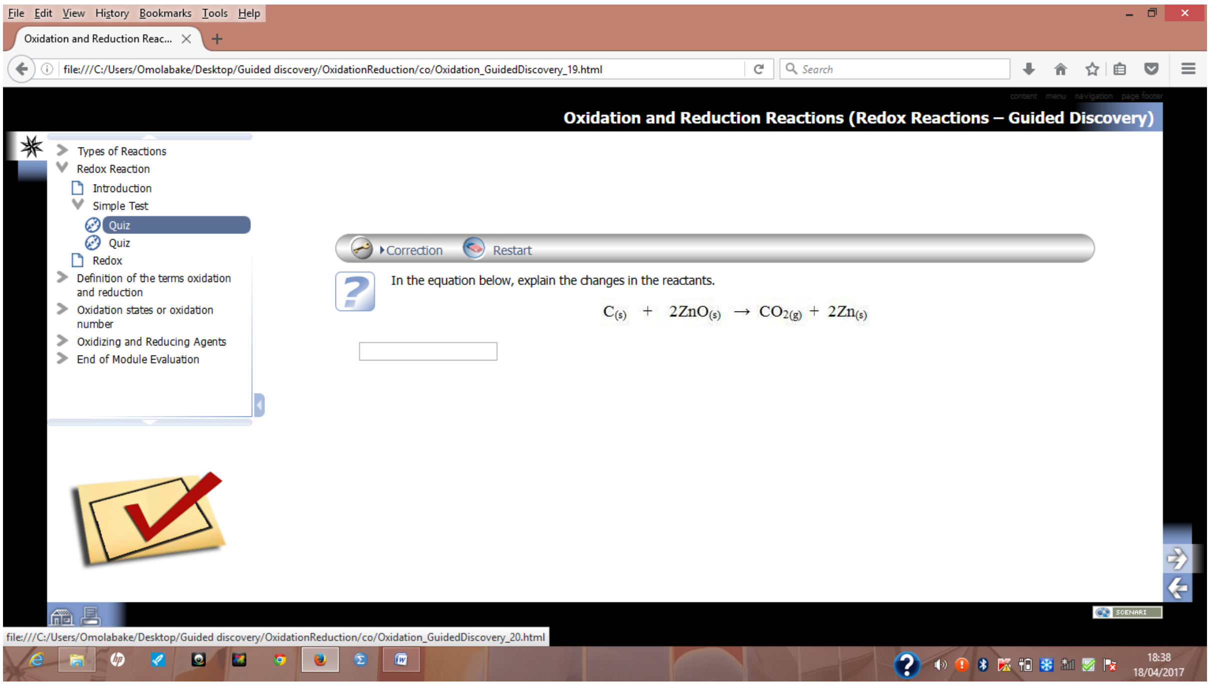
Oxidation and Reduction Reac...
file:///C:/Users/Omolabake/Desktop/Guided discovery/OxidationReduction/co/Oxidation_GuidedDiscovery_30.html
Oxidation and Reduction Reactions (Redox Reactions – Guided Discovery)
Oxidation and reduction - example 1
Exercise 1
Oxidation and reduction - example 2
Exercise 2
Question to think about
Direction of Electronegativity and Electropositivity of Elements
Oxidation and reduction - example 3
Exercise 3
Direction of oxidation an reduction
Oxidation states or oxidation number
Electropositivity meter
Elements (metals) K, Na, Ca, Mg, Al, Zn, Fe, Pb, Cu
Electropositivity series
18:37
18/04/2017

End of Module Evaluation



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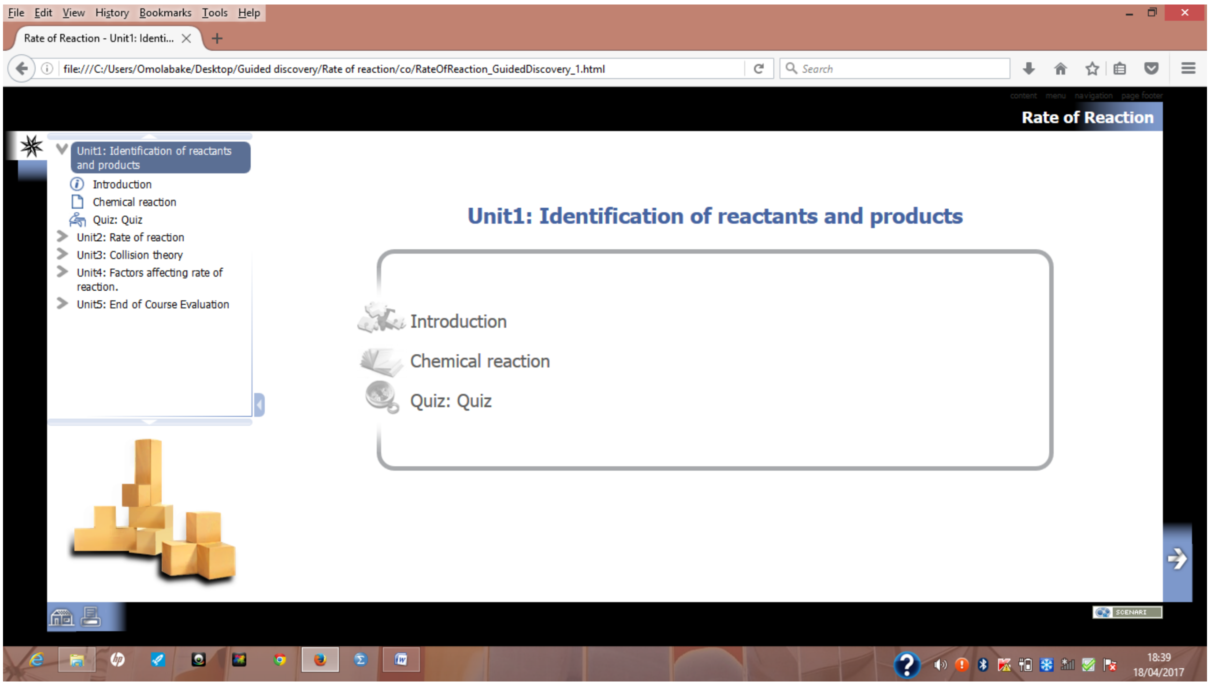

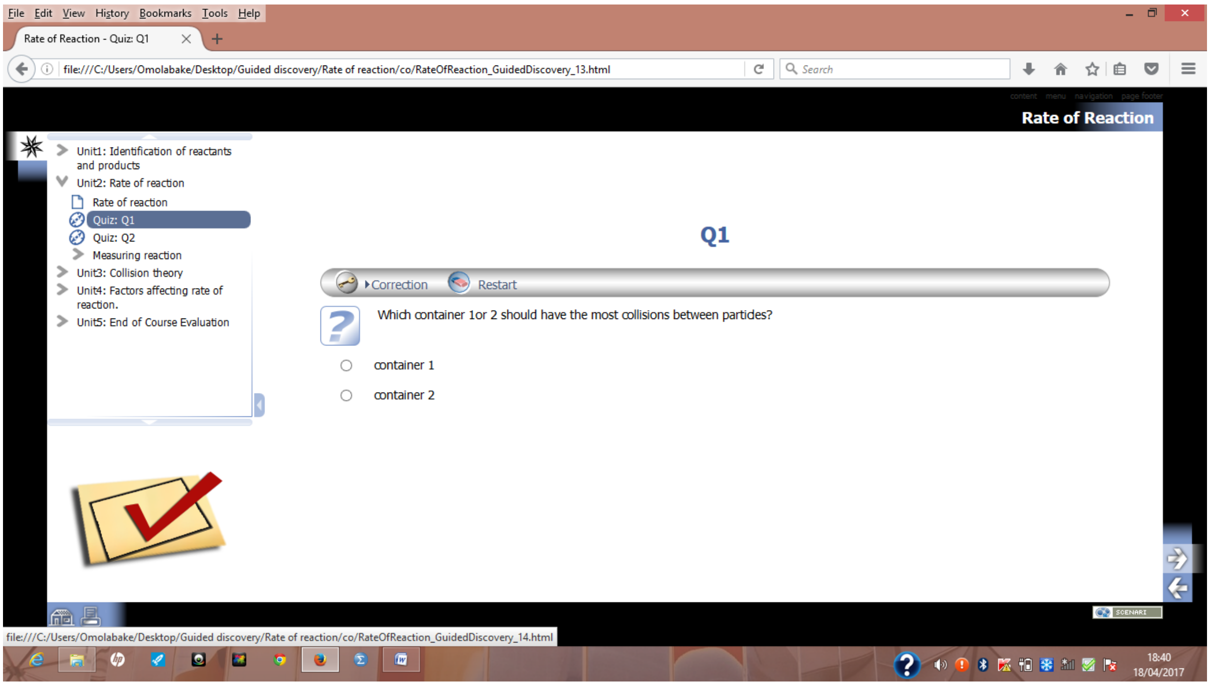
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Rate of Reaction - Quiz: Q1
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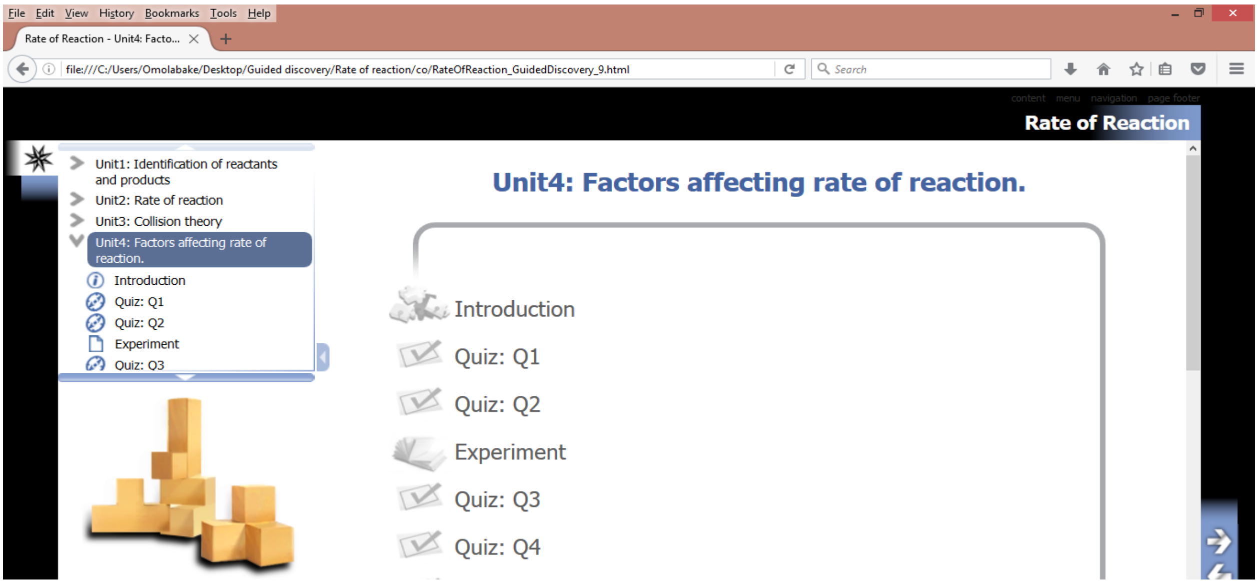
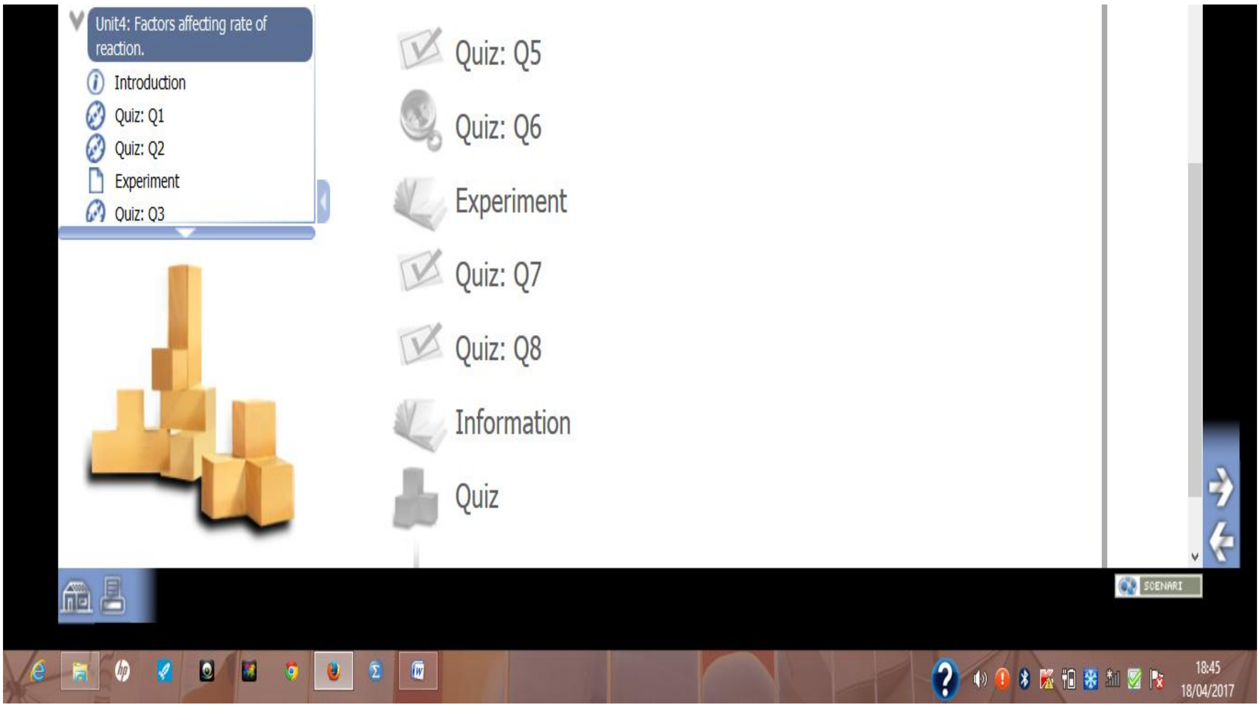
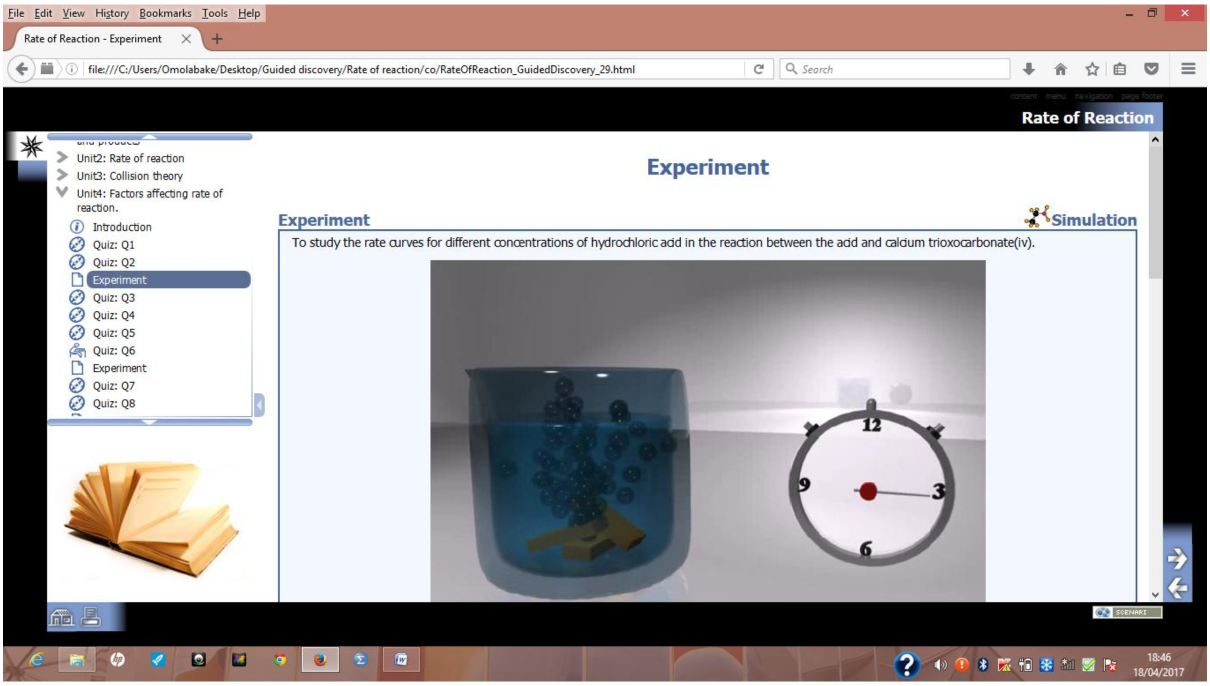
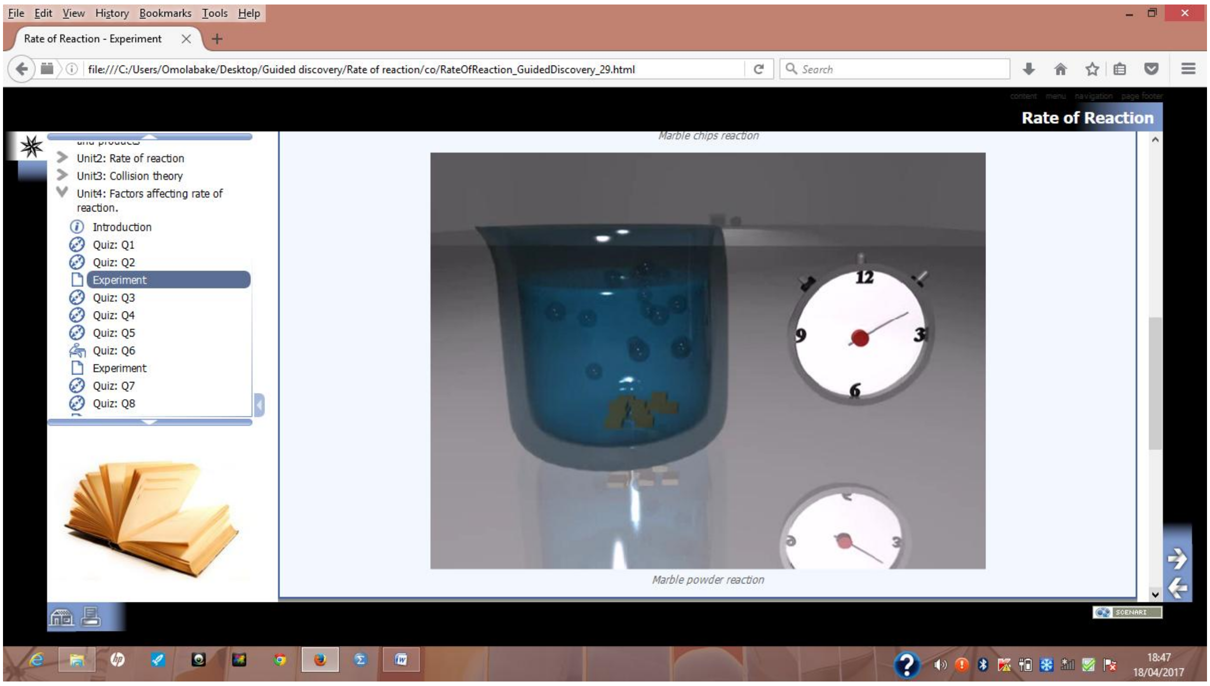
Rate of Reaction
Unit1: Identification of reactants and products
Unit2: Rate of reaction
Rate of reaction
Quiz: Q1
Quiz: Q2
Measuring reaction
Unit3: Collision theory
Unit4: Factors affecting rate of reaction.
Unit5: End of Course Evaluation
Q1
Correction
Restart
Which container 1or 2 should have the most collisions between particles?
container 1
container 2
file:///C:/Users/Omolabake/Desktop/Guided discovery/Rate of reaction/co/RateOfReaction_GuidedDiscovery_14.html
18:40
18/04/2017

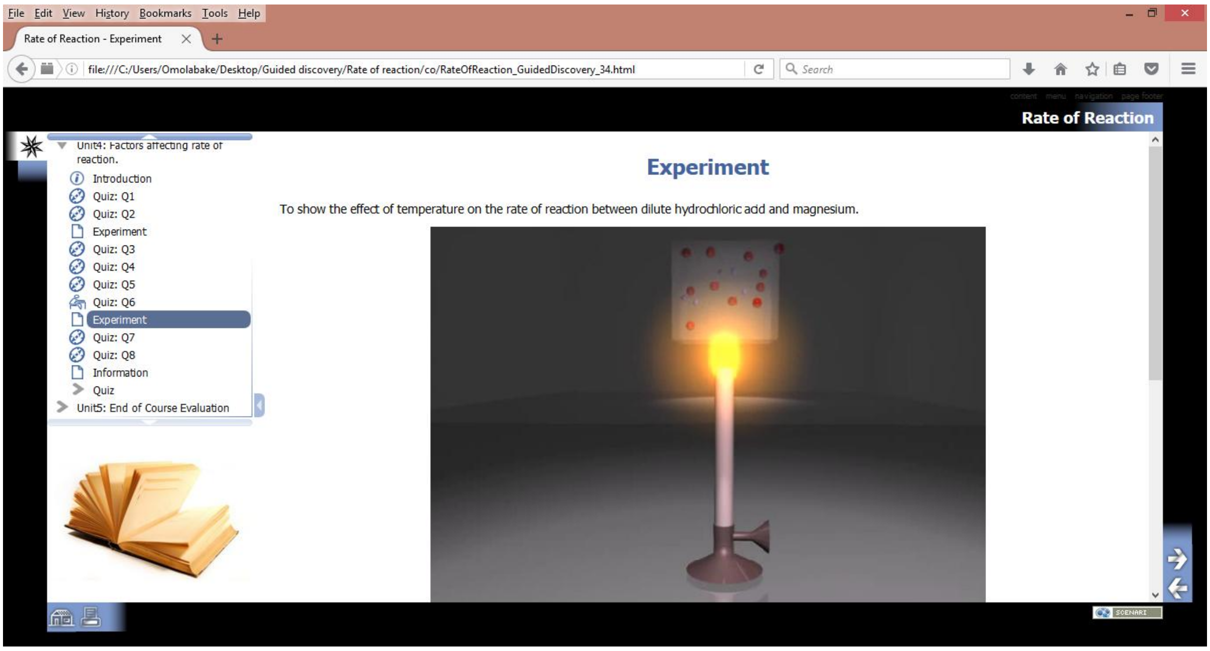
Factors Affecting Rate of Chemical Reaction






Rate of Reaction - Experiment
Rate of Reaction
Unit2: Rate of reaction
Unit3: Collision theory
Unit4: Factors affecting rate of reaction.
Introduction
Quiz: Q1
Quiz: Q2
Experiment
Quiz: Q3
Quiz: Q4
Quiz: Q5
Quiz: Q6
Experiment
Quiz: Q7
Quiz: Q8
Experiment
Experiment
Simulation
To study the rate curves for different concentrations of hydrochloric acid in the reaction between the acid and calcium trioxocarbonate(iv).


Rate of Reaction - Experiment
Rate of Reaction
Unit2: Rate of reaction
Unit3: Collision theory
Unit4: Factors affecting rate of reaction.
Introduction
Quiz: Q1
Quiz: Q2
Experiment
Quiz: Q3
Quiz: Q4
Quiz: Q5
Quiz: Q6
Experiment
Quiz: Q7
Quiz: Q8
Marble chips reaction
Marble powder reaction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Rate of Reaction - Experiment
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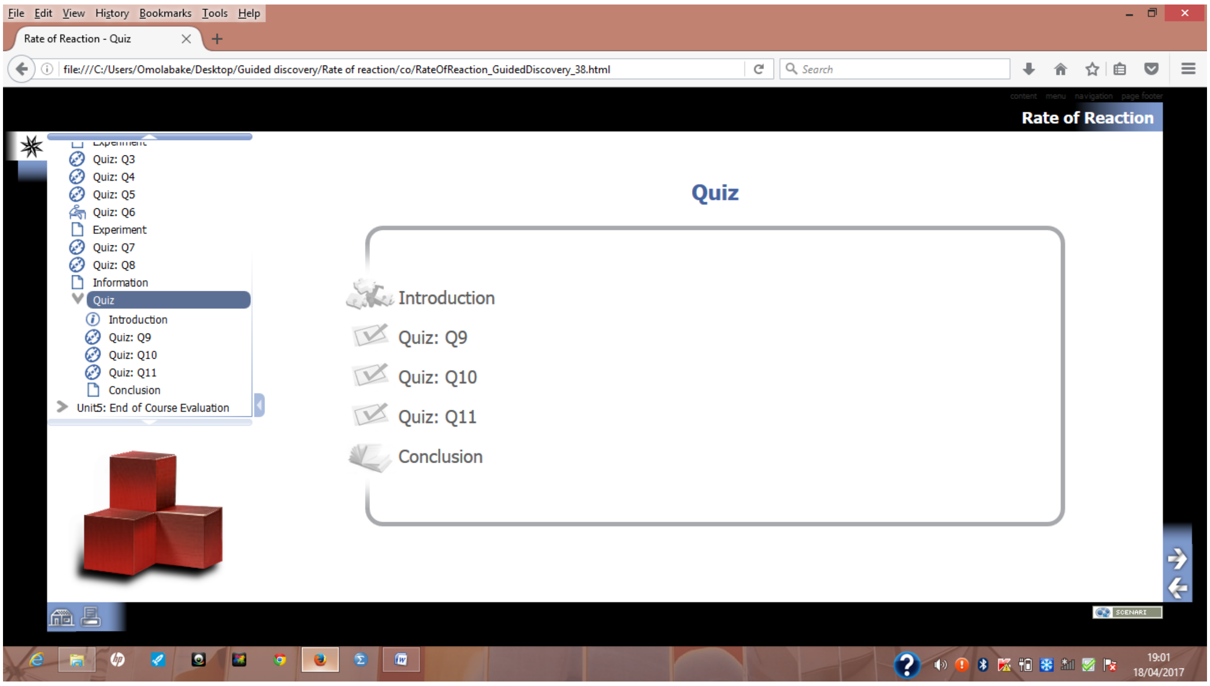
Rate of Reaction
Unit4: Factors affecting rate of reaction.
Introduction
Quiz: Q1
Quiz: Q2
Experiment
Quiz: Q3
Quiz: Q4
Quiz: Q5
Quiz: Q6
Experiment
Quiz: Q7
Quiz: Q8
Information
Quiz
Unit5: End of Course Evaluation
Experiment
To show the effect of temperature on the rate of reaction between dilute hydrochloric acid and magnesium.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Rate of Reaction - Quiz
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Rate of Reaction
Quiz: Q3
Quiz: Q4
Quiz: Q5
Quiz: Q6
Experiment
Quiz: Q7
Quiz: Q8
Information
Quiz
Introduction
Quiz: Q9
Quiz: Q10
Quiz: Q11
Conclusion
Unit5: End of Course Evaluation
Quiz
Introduction
Quiz: Q9
Quiz: Q10
Quiz: Q11
Conclusion
19:01
18/04/2017

APPENDIX XII

SAMPLED SCHOOLS WITH THE TEACHING STRATEGIES EMPLOYED BY THE CHEMISTRY TEACHERS

SCHOOL	TYPE	TEACHING STRATEGIES
1	PRIVATE	GD
2	PRIVATE	IGD
3	PRIVATE	ITD
4	PRIVATE	TD
5	PUBLIC	TD
6	PUBLIC	TD
7	PUBLIC	IGD
8	PUBLIC	ITD
9	PUBLIC	ITD
10	PUBLIC	GD
11	PUBLIC	IGD
12	PUBLIC	GD