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**ABSTRACT**

This study investigated the effects of chemical concept understanding level on students' achievement in biochemical topics (photosynthesis, respiration, diffusion and osmosis, carbohydrates, protein, fats and enzymes) in some selected secondary schools in Delta State of Nigeria. The study made use of mixed method research approach. Quantitatively, the design of the study was quasi experimental non-randomized pre-test and post-test control group design. A case study Embedded Design was adopted to take care of the qualitative aspect of the mixed method study. Kuder-Richardson formula 20 (K-R20) was used to calculate the reliability coefficient of the test. The internal consistency of reliability co-efficient was calculated to be 0.76 that made the instrument to be accepted as reliable for the study. The population of this study consisted of all senior secondary (II) biology students in the twenty (25) local government areas of Delta State of Nigeria. Six secondary schools randomly selected from the three senatorial districts of the State were used for the study, with three (3) schools for experiments specially taught with emphasis on both ideas (concepts) and skills, problem-based interactive learning ensuring concept connections and the other three (3) for control groups. Intact classes were used for both groups. The intact sample was made up of five hundred and ninety two (592) students for the quantitative study; while two teachers and four students were purposively sampled for the qualitative aspect of the study. Four (4) research questions were raised and answered and four (4) null hypotheses were formulated and tested at 0.05 level of significance. The research instruments used were the Test of Students Understanding of Chemical Concepts (TOSUCC), Biology Achievement Test (BAT) which measured achievement in biochemical topics and Interview Schedules for both teachers and students. The quantitative data collected were analysed using Analysis of Covariance (ANCOVA) for the hypotheses and mean ratings for the research questions; and the qualitative data were analysed by coding and themes generation and interpretations. Findings show that the experimental group performed better than the control group in the biochemical topics. An effect size of Cohen`s d equal to 0.996 was determined from the mean scores and standard deviations of the experimental and control samples for the study. Therefore, the experimental group had better achievement because determined effect size seemed large enough in favour of the treatment group. No significant interaction effects of gender and location on students` level of achievement in both experimental and control groups were established by the study. The teachers in particular should use the outcome of this study to improve on their teaching, emphasizing on concept understanding in their teaching and prior learning/knowledge or pre – requisite concepts. This is because certain chemical concepts are required before the teaching of the main topics (Biochemical topics in this case). In other words, this study recommends that secondary school biology and chemistry teachers should teach for concept understanding, topics that are related to the new topics before teaching the topics.

**Key Words**

Achievement, biochemistry, biochemical topics, biology, chemical concepts, concept understanding level, and prior knowledge

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background of the study

Science education is very important for the development of any nation. Many studies have been carried out to find out about the performance of students in science and biology in particular (Rytkonen, Parpala, Lindblom-Ylanne, Virtanen and Postaneff, 2012; Mohammad, 2014). Biology, the study of life, is a branch of natural sciences. It has many branches like genetics, biochemistry, physiology, anatomy, ecology, entomology, evolution, molecular biology, geography, mathematics, physics, and zoology. It is one of the most important subjects in the Nigeria secondary school curriculum. It is required for the study of several science courses like biochemistry, microbiology, botany, medicine, nursing pharmacy and agriculture. Biology is compulsory and it is taken by all senior secondary school students in the Senior School Certificate Examination (SSCE) in Nigeria.

Performance of students in secondary schools has been poor, despite the fact that biology is important and popular among Nigerian students (Egbunonu and Ugbaja, 2011). Okoye and Okeke (2007) in their study found that between 2002 and 2004 the percentages of candidates who passed West African School Certificate Examination (WASCE) at credit level and above (grades 1 – 6) in biology were 30.3% in 2002; 42.1% in 2003 and 30.7% in 2004. Egbunonu and Ugbaja (2011) also reported that only 30.2% of the biology students who sat for WASCE between 2000 and 2005 passed at credit level and above (A1 – C6). The WAEC chief examiner`s report of 2012 stated that there was a decline in performance in biology, especially in the theoretical aspects (WAEC 2012). Nigerian Television Authority once reported that the National Examination Council (NECO) recorded 74% failure in their Nov/Dec 2009 NECO examination result. Furthermore, the West African Examinations Council (WAEC), (2012) Chief Examiners' Reports showed the senior secondary certificate examination results for biology May/June from 2007 – 2012 examinations as in the table below:

Table 1: Statistics of Biology results in May/June SSCE for 2007-2012

| Year | Total that enrolled | Total no. of candidates that sat for the exam | Numbers and percentage of different grades | | |
|---|---|---|---|---|---|
| | | | Credit (1-6) | Pass (7-8) | Fail (9) |
| 2007 | 656,105 | 609,026 (92.27%) | 96,202 (15.79%) | 142,044 (23.32%) | 370.800 (60.88%) |
| 2008 | 880,089 | 841,868 (95.46%) | 36,348 (31.29%) | 286,909 (34.08%) | 291,475 (34.62%) |
| 2009 | 1,065,854 | 1,036,520 (97.17%) | 322,310 (31.39%) | 365,140 (35.57%) | 339,070 (33.03%) |
| 2010 | 1,210,126 | 1203,028 (99.41%) | 466,115 (38.75%) | 354,108 (29.43%) | 319,060 (26.52%) |
| 2011 | 1,396,352 | 1347,050 (96.34%) | 492,422 (36.56%) | 409,584 (30.41%) | 362,238 (26.89%) |
| 2012 | 1,511,996 | 1,476,991 (97.63%) | 488,302 (31.81%) | 478,840 (31.19%) | 509,849 (33.21%) |

Source: WAEC Annual Report 2007-2012

Many teachers, parents, curriculum planners, researchers and the government according to Egbunonu and Ugbaja (2011) are greatly concerned about the poor academic performance of students in many subjects, particularly biology. Many factors have been identified to be responsible for the poor performance of students in biology senior secondary school certificate examinations. Some of these factors according to Osuafor and Okonkwo (2013) are lack of qualified teachers, lack of educational facilities like laboratories, overloaded syllabuses, laziness, poor attitude to work and lack of interest on the part of students, poor teaching methods by teachers, large classes size and high teacher/student ratio and family or home background of the students. They emphasized, that apart from the inter-relatedness that exists among these factors, biology is closely related to other science subjects like agriculture, chemistry, biochemistry, physics, mathematics and geography that contribute the problems in biology.

Biochemistry is a branch of chemistry and biology. It is the study of the chemistry of life. Webster's Dictionary (2010) defined biochemistry as a science that deals with the chemistry of life processes in plants and animals. Living things are made up cells and biochemistry studies the chemical components of the cells, chemical reactions and processes that take place in the cells. Biochemistry therefore is the study of the molecules and chemical reactions that take place in living things. The aim of biochemistry is to understand the chemical reactions and processes of all living things at the molecular level. To achieve this aim, the different molecules in the cells are isolated, and analyzed to determine their structures and functions. Biochemistry is important for the study of all life sciences. It is important for the study of genetics, physiology, pharmacology, pathology, microbiology, zoology, botany and medicine. Some of the biochemical topics in the Federal Ministry of Education Senior

Secondary Core Curriculum for biology in Nigeria are: Cellular respiration, Photosynthesis, Carbohydrate, Protein, fat, osmosis and diffusion. These are all biochemical processes and concepts which are related such that a firm understanding of one enhances deeper and faster understanding of the other.

A concept according to Kernerman (2010), is a general notion or idea of about anything or object. An idea or concept is formed by mentally combining all its characteristics or particulars in a meaningful way. Concepts enable us to organize learned responses which help us to organize and interpret data. Also, a concept enables us to respond effectively and understand the complexity of the world. The chemist who has mastered the concepts of his discipline will be able to plan and control complex chemical processes to produce new products like liquid soap, perfumes and plastics. The key to understanding a subject is to understand its concepts. These concepts are identified with words, symbols, formulae. To know a subject is to know the meanings attached to the words which represent its concepts. Once the concepts have been learned we can apply them in new instances that share the same and similar important characteristics.

Chemistry which is also related to biology is the study of the composition and properties of matter, changes in matter, and the laws and principles that govern these changes (Ababio, 2008). Some chemical concepts in the curriculum of Junior Secondary School are: physical and chemical changes, elements, compounds and mixtures, chemical symbols, chemical formula, chemical equation and atomic structure.

The understanding of biochemical topics requires the knowledge of some chemical concepts. Beskeni, Yusuf, Awang, Ranjha (2011) investigated the effect of students' prior knowledge on the understanding of difficult chemistry concepts at secondary school level teaching, and found that the students' prior knowledge, improved their learning and understanding of difficult chemistry concepts. For effective teaching and learning of chemistry, prior knowledge must be considered in any classroom situation. Many teachers, from my experience as a biology and integrated science teacher, skip the teaching of some important chemical concepts in Integrated Science that would lay a foundation for the learning of carbohydrate, proteins, photosynthesis, respiration, and enzymes which are abstract. As a result, students do not understand these topics and so, memorize without grasping the meaning of the concepts. This statement is supported by Bhinyo, Pintip and Namkang (2008), who stated that students could not apply basic knowledge to answer questions in biology because they did not understand the main concepts.

Villafane, Loertscher, Minderhout, Lewis (2011), explained that students' learning in biochemistry depends on the application of priorly learned concepts from general chemistry and biology and it is related to the new learning. This makes biochemistry a challenging subject to both teachers and students. For meaningful learning to take place, the learning must have relevant concepts available within the existing cognitive structure which can be linked with the new material.

Conceptual understanding has been used overtime in science education literature. Science educators have seen the need teach for concept understanding. Simply put, concept understanding means deep understanding of the concept (idea) that was learnt. Hamzah and Ahmed (2010) defined conceptual understanding as an integrated and functional grasp of an idea or concept. Mohammad (2014); Gobert, O'Dweyer, Hartwitz, Buckley, Levy, and Wilensky (2011) explained that conceptual knowledge is the knowledge rich in relationship and understanding. She added that it is a connected web of knowledge, a network in which the relationships are as prominent as the discrete bits of information. Novak (1977) defined concepts (also known as constructs) as what we think. Wiggin and McTighe (2005) defined concept as a mental construct represented by phrase. They said a concept can be tangible objects like leaf, stem, heart, feathers or abstract ideas like bravery, inquiry, democracy. Scientists use classification, context and evidence to investigate concepts. Concepts and constructs are interchangeably used.

Wiggin and McTighe (2012) explained that understanding is revealed when students autonomously make sense of and transfer their learning through authentic performance. Six factors of understanding from understanding by design (Wiggins and McTighe, 1998) explain that when one understands:

1. One can explain and understanding enables one to answers questions like:
    - Why is this so?
    - What explains such events?
    - How does this work?
    - How can we prove it?
2. One can interpret: Understanding enables one to answer questions like:
    - What does it mean?
    - Why does it matter?
    - How does it relate to me?
3. One can apply: Understanding enables one to answer questions like:
    - How and where can we use this knowledge, skill and process?
4. Has perspective: Understanding enables one to answer questions like:
    - Is there adequate evidence?
    - Is it reasonable?
    - What are the strengths and weaknesses of the idea?

5. Can empathize: Understanding enables one to answer questions like:
    - How does it seem to you?
    - What do they see that I don't?
    - What do I need to experience if I am to understand?
6. Has self-knowledge: Understanding enables one to answer questions like:
    - What are the limits of my understanding?
    - What are my blind spots?

According to Hamzah and Ahmed (2010) students with conceptual understanding, understand when an information or idea or concept is important and the kind of context in which they can be used to

- Organize their knowledge to enable them learn new ideas by connecting the already known or what they will encounter in future;
- Understand, communicate and apply scientific laws, theories, principles and concepts to make scientific decisions;
- Can retain what they have learnt with understanding;
- Can reconstruct ideas or concepts when forgotten;
- Can apply what they have learnt in their day to day activities.

Ceylan and Geban (2010) reported that conceptual understanding simply means having a deep understanding of the concept (idea) that has been learnt. They added that conceptual knowledge cannot be gained by rote learning; it must be learnt by thoughtfulness and reflective learning. According to Finch (2015), conceptual understanding involves an individual understanding of the principles of science and predict observations of the natural world and knowing how to apply their understanding efficiently in the design and execution of scientific investigations and in practical reasoning.

A reform document of America Association for Advancement of Science (AAAS, 2008) also emphasized the need to develop students' conceptual understanding and scientific literacy by using inquiry and problem solving experiences and skills acquisition. According to Ibrahim, Eridal and Mustapha (2010) a conceptual instruction method is a process of acquiring a better understanding of concepts. Science Teachers Association of Nigeria (STAN) and Nigerian Education Research Development Council (NERDC) in the past twenty years have aimed at stimulating interest in science at all levels of education. They have looked into curriculum modification, innovations, teaching methods, teaching facilities, and students' factors. Even with all these progress and concerns, teaching strategies that have been shown to be effective are still not widely used. Many people are unaware that these strategies exist and have been shown to be effective (Henderson and Dolan, 2011). Andrew, Leonard, Celgrove and Kakinowski (2011) added that others lack the knowledge of how to use research to improve instruction. Institutional and cultural barriers show or even prevent faculty members from adopting teaching methods demonstrated to be beneficial, precluding widespread employment of effective instructive practice (Brewness and Tanner, 2012). To address this situation, there is need to publish more researches that will break new ground in understanding biology teaching and learning and educational innovations that has been evaluated for efficacy. According to Jegede (2010), one of the factors that affect concept understanding which has not received much attention is the role of conceptual instruction. The National Science Teachers Association (2014) reported that current research indicates that young children have the capacity for constructing conceptual learning and the ability to use the practices of reasoning and inquiry. Even with all these, Kathleen (2014) stated that children in United States perform poorly on assessment, regarding their understanding of both plants and the life sciences in general. For example, data from National Centre for Education from 2009 showed that the national average score in the life sciences for grade four (4) students was one hundred fifty, out of three hundred, with a finding grade of fifty percent (150 out of 300 – a finding grade of 50%) in the United States of America.

The uniqueness of Biology and the central role that it stands to play in the development of any nation, are however not evident in the performance of students. It is sad to note that students` performance in Biology has continuously been poor and unimpressive. Many Researches have been conducted and are still being conducted to enhance the performance of students in biology, with a view to providing solutions to the low performance problem. Hence the present study is to find out the effects of chemical concept understanding level on students' achievement in biochemical topics, with the hope that chemical concepts would be taught before the biochemical topics for better understanding and achievement in biology.

## 1.2 Statement of the Problem

Biology as a school subject occupies a position as one of the core subject for students pursuing a career in science and technology as a field of study. The drive for scientific and technological development is a cry of successive governments in Nigeria. To this end there are obvious high investments by government in the teaching and learning of science subjects among which is Biology. It is worthy of note that the importance of biology as well as the huge investment by government for its teaching and learning do not correspond to students achievement in the subject (AAAS, 2008).

The chief examiner's report of the West African Examination Council (WAEC, 2012), the body charged with the responsibility of conducting senior school leaving certificate examination, report on Chemistry and Biology students' achievement had shown an unimpressive performance of students over the years. The effort to provide answers to student's poor performance in students learning is not new. Most recent research effort however had focused on pedagogy, with obvious complains against the traditional lecture method and a call for the use of more interactive teaching methods (Omoifo, 2012). While recognizing the role of teaching method and strategies in teaching and learning, the peculiarity of specific topics within the subject are areas worthy of note in addressing students' poor academic achievement. The WAEC examiners report of 2010 – 2012 identified specific topics where students' achievements in Chemistry and Biology are particularly poor. They include writing of chemical formulae, balancing of equations, and poor knowledge of IUPAC nomenclature especially organic compounds among others. Ironically, these are areas of interest in Biology.

The interrelatedness of subjects such as Biology and Chemistry demand the good understanding of related concept areas of one of the subjects which enhances learning in other subject. The concepts students find difficult in Chemistry are more or less the areas where learning interference exist with poor achievement in biochemical topics due to the difficulty in learning chemical concepts. In other words, lack of appropriate and deep conceptual understanding resulting from poor teaching methods and strategies could affect the achievement of students in any given subject. The problem of this study therefore, was to determine the effects of chemical concept understanding level on students' achievement in biochemical topics in other to enhance the teaching and learning of biochemical topics and consequently enhance students' achievement in Biology.

## 1.3 Research Questions

To address this problem, the following research questions were raised:

1. Is there a difference in students' chemical concept understanding level between students exposed and those not exposed to instructions on chemical concepts (physical and chemical change, elements, compounds, mixtures, valency, chemical symbol, chemical formula, simple equation, and atomic structure)?
2. Is there a difference in achievement level in biochemical topics (photosynthesis; respiration; diffusion and osmosis; carbohydrates, proteins, fats and enzymes) between students exposed to instruction in chemical concepts and those not exposed to instructions in chemical concepts?
3. Is there any gender interaction effect of students on their achievement in biochemical topics?
4. Is there any location interaction effect of students exposed and those not exposed to instructions in chemical concepts on their achievement in biochemical topics?

## 1.4 Hypotheses of the Study

The following null hypotheses were tested at $p \leq 0.05$ for the study:

1. There is no statistically significant difference in students` level of conceptual understanding between students exposed and those not exposed to instructions on chemical concepts.
2. There is no statistically significant difference in achievement level between students exposed and those not exposed to instructions in chemical concepts before being taught biochemical topics.
3. There is no statistically significant gender interaction effect on achievement in

biochemical topics of students exposed and those not exposed to instruction in chemical concepts.

4. There is no statistically significant location interaction effect on their achievement in biochemical topics of students exposed and those not exposed to instructions in chemical concepts.

## 1.5 Purpose of the Study

This study was to determine the effects of chemical concepts understanding level on students' achievement in biochemical topics. It was specifically to find out:

1. If there is any significant difference in students understanding of biochemical concepts after being exposed to instructions on chemical concepts.
2. If there is any significant difference between biology students exposed to instructions in chemical concepts and those not exposed to chemical concepts in their achievement test.
3. If there is any significant differential gender effect on students exposed to instructions in chemical concepts and those not exposed to instructions in chemical concepts in their achievement in biochemical topics.
4. If there is any significant location interaction effect on students exposed to instruction in chemical concepts and those not exposed to instructions in chemical concepts in their achievement in biochemical topics.

## 1.6 Significance of the Study

The findings of this study would be of benefit to biology and integrated science teachers, researchers, curriculum planners as well as the Behaviour Changing Agents in order to develop a greater awareness and understanding of the various intervening variables that can affect the academic performance of students.

1. The study would help teachers to emphasize and teach for concept

understanding, relating the concepts or topics and their environment. The student will eventually benefit greatly from this study since students with academic success will eventually contribute to the social, industrial and technological advancement of the nation.

2. The study`s recommendations will make it possible for other researchers to develop further experimental researches in future in order to contain the variables investigated herein.

3. The study will serve as basis a basis for designing intervention programs for improving the academic performance of students who could be described as low achievers.

## 1.7 Scope and Delimitation of the Study

The study examined the effects of chemical concept understanding level on students' achievement in biochemical topics. Topics covered in the period of study were integrated science chemical concepts of physical and chemical change, elements, compounds, mixtures, valency, chemical symbol, chemical formula, simple equation, and atomic structure) and biology biochemical concepts of photosynthesis; respiration; diffusion and osmosis; carbohydrates, proteins, fats and enzymes) as drawn from the junior secondary school and senior secondary school official schemes of work.

## 1.8 Operational Definition of Terms

- **Chemical Concepts –** These are chemistry concepts such as physical and chemical change, elements, compounds, mixtures, valency, chemical symbol, chemical formula, simple equation, and atomic structure. They are expected to be well taught to students in integrated science as a subject at the junior secondary school level for future applications in other related subjects.

- **Biochemical topics** as used in this study are photosynthesis; respiration; diffusion and osmosis; carbohydrates, proteins, fats and enzymes in the senior secondary school biology which are biochemical processes.
- **Prior knowledge** in this study means the form or type of knowledge acquired based on previous experience of the student.
- **Concept understanding**: This is making meaning out of the ideas presented in a study in such a way that the student will be able to comprehend and apply them in other related instances or subjects.
- **Understanding level –** For this study the mean score of less than fifty (50%) percent and more than fifty (50%) is an indication of low and high understanding level respectively. It is a measure of how much an information must have been integrated into the student`s conceptual framework.

# CHAPTER TWO

# REVIEW OF RELATED LITERATURE

The review of literature was based on the following:

1. Conceptual framework
2. Prior Knowledge and Assessment
3. Biology as a Subject in Nigerian Secondary School.

   Some factors that affect understanding and achievement in biology: Teachers' attitude to teaching biology; nature of the subject; home background; attitude of student to biology.
4. Biochemical topics / chemical concepts; challenges of learning biochemical topics.
5. Some empirical studies on achievement,
6. Appraisal

## 2.1 Conceptual Framework

Learning is meaningful when there is conceptual change, which has to do with understanding of the new concept that is learnt, and the meaningful understanding is likened to conceptual understanding. According to Ausubel (1968) if there is no link between the new concepts with existing information (prior knowledge), the new concepts will not be meaningful to the learner, rather he/she will resort to memorization. The most important factor influencing the meaningful learning of any new idea is the state of the individuals existing cognitive structure at the time of the learning (Ausubel and Robinson, 1969). They explained that the goal of the instruction is to allow learners to integrate new knowledge with existing knowledge structure for longer retention and the ability to apply and transfer it to their contexts. According to Ausubel (1968) all knowledge is organized in hierarchical cognitive structure that is unique to the individual. Within these cognitive structures, minor element of new knowledge are lined or subsumed under larger or more in closure concepts. The most important piece of instruction is to provide cognitive bridge to make it possible for learners to assimilate new knowledge. Usually these are in the form of advance organizers such as graphs, concept maps or photographs of the phenomenon to be studied. All these have to do with constructiveness. Good and Brophy (1986) stated that the constructivists view learning as depending on the degree to which learners can activate existing structures or construct new ones to subsume the input. So a teacher must have an idea of what the students already known in order to guide the learning.

Research has shown that many students do not correctly understand fundamental chemistry concepts (Orgil and Bodner, 2007). Students do not fully understanding fundamental concepts; many students have troubles in understanding the more advanced concepts that build upon the fundamental concepts. Anderson (2007) said, despite the importance of fundamental chemistry, most students still emerge from introductory course with very limited understanding of the subject .Chemistry has been regarded as a difficult subject by students, many researchers, teachers and science educators (Reid, 2008; Cimer, 2010). This difficulty according to them is attributed to the abstract nature of many chemical concepts, teaching styles applied in class, lack of teaching aids and the difficulty of the language of chemistry. All these cause students from primary to university level to develop poor understanding of the concepts.

Ibrahim (2006, pp. 34) reviewed the possibility of deriving design principles from schema theory in connection with conceptual understanding proving three some three theoretical claims of schema. They are as follows:

a) The level and quality of understanding any given new concept depends on the already existing schemas. This implies activating one`s prior knowledge which should be relevant to the new concept being learned.
b) That interpretation of the new concept should be by accretion, turning, restricting or creation learning modes for the new concept to make meaning to the student (Konicek-Moran, 2015; Konicek-Moran and Keeley, (2015)). It enables students to think deeply on the idea being learned.
c) Students tend to reason based on concrete ideas at the Concrete Operational Stage. This is the situation where the teacher endeavors to eliminate abstractness concerning concepts being taught.

## 2.2 Prior knowledge

For several decades, learning has been a topic of research by science educators including biology and chemical educators (Orgill and Bodmer 2007, Minano and Castejon, 2011). The focus has been on why students have difficulty learning science (Cimer 2010, Myuzammila, Johan and Murad 2014). Other researchers focused on how students learn. To address these problems, different theories and models were developed by the researchers to examine how students learn.

In the last two decades, research in science education has focused on the fact that students' learning is constructed in the mind of the learner. Researchers found that prior knowledge has great influence on their ability to build new scientific concepts. If students' prior knowledge is incomplete, poor or disconnected, they are likely not to understand the new information (Minano and Castejon, 2011).

The learning theories proposed by Piaget, Bruner, Ausubel, Vygotsky, and Feuerstein all emphasized the importance of prior knowledge learning experience as basis for further learning. This study is influenced mostly by Ausubel’s theory of meaningful learning. He developed a theory of learning which distinguished between rote learning and meaningful learning.

When Ausubel introduced his theory of meaningful learning, his emphasis was on meaningful learning. Ausubel (1968) defined meaningful learning as non-arbitrary, non-verbatim, substantive incorporation of new symbolically expressed ideas into cognitive structures. According to him, a learner relates new information or ideas to relevant aspects of current knowledge structure in a conscious manner. He stated that for meaningful learning to take place, three conditions must be met:

- The material to learn must have potential meaning;
- The learner must possess relevant concepts and proposition that can serve to anchor the new learning and assimilate new ideas;
- The learner must choose to relate the new information to his/her cognitive structure in a non-verbatim, substantive fashion. If any of those three elements is missing, meaningful learning cannot occur, at least in initial (beginning) stages of a given learning sequence.

Ausubel advocated for the use of advance organizer. Organizer proposed stated that:

- Instructions should be organized in such a way that more general concepts/propositions are introduced in a concise fashion prior to more specific and less inclusive prepositional material.
- This general and more abstract introduction of ideas serve to anchor into cognitive structure of more specific information to be learnt subsequently.

Ausubel explained that for advance organizer to work, they should be relatable to existing concepts and propositional meanings in the learners’ cognitive structures;

they should be relatable also to the subsequent information to be taught. He summarize by saying; advanced organizer should be devised and be related to the existing cognitive structure, the necessity for the learner to choose to learn meaningfully and/or the necessarily, to evaluate meaningful learning with appropriate test material.

According to Novak (2011), the learners seek to integrate new knowledge with relevant existing knowledge in a meaningful learning process. Adodo and Gbone (2010) reminded teachers about the strength of prior knowledge of basic science concepts in teaching basic science which has to do with Ausubei's belief that meaningful learning occurs when there is interaction between the learners' appropriate elements in the knowledge that already exists and the new material to be learnt. Stressing the importance of prior knowledge (Akanbi and Kolawole 2014) stated that in teaching for understanding of major concepts in biology and achieving conceptual change in students' learning outcome, it is necessary to first understand students' prior knowledge, examine it, identify confusion and then provide opportunities for old and new ideas to collide. If at the end of the study the students show signs of having incorporated the new knowledge about chemical reaction and chemical change, especially redox reactions, to the knowledge gained from past grade levels one might say that they have learnt the concepts meaningfully (Muwanga-Zakes, 2007). According to Nunez, Vallejo, Rosario, Tuero and Valle (2014) Knowledge should be organized hierarchically for students to understand the new experiences. Minano and Castejon (2011) noted that the acquisition of new knowledge can be seriously compromised by severe gaps in prior knowledge.

According to constructivism, learning is a cognitive process and occurs by construction of knowledge in the mind of the learner. Hartle, Raviskar and Smith

(2013) explained that Learners 'construct' knowledge by modifying and contributing to their existing mental construct. Existing mental construct is known as prior knowledge. Many factors affect concept understanding. The most important of which is the student's prior knowledge. Research in science education therefore has focused on studies, which ensure the effective construction of knowledge, and prevent the formation of misconceptions (Acar and Tarhan, 2007).

Prior knowledge is one of the factors that affect teaching and learning of science. It seems to be a common feeling by various people that boys achieve higher than girls given the same condition of exposure to prior knowledge of instructional objective of physics difficult concepts. In the study carried out by Henderson and Dolan, (2011), students' alternative conceptions and instructional strategies that affect learning of scientific conceptions in South Africa, by using their priory identified prior knowledge. Their finding showed a significant improvement in the acquisition of scientific conceptions as a result of the instructional strategy and materials which explicitly dealt with students' alternative conceptions of mass, volume and density, and concluded that prior knowledge was one of the factors affecting knowledge. Telle (2009) defined prior knowledge as knowledge that is presented before the implementation of a particular learning task. The knowledge is available and could be recalled or reconstructed, and to some extent transferrable or applicable to other learning tasks. Prior knowledge or prior understanding is an important influence on new learning.

### 2.3 Students assessment in science

Judgment of students work is usually referred to as assessment. William and Black (1996) defined assessment as a process that is characterized as a cycle that involves elicitation and production of evidence which when interpreted appropriately, may lead to action which in turn can yield to further evidence and so on. Assessment can be formative or summative. Summative assessment is the traditional type of assessment that is used at the end of the term, course or performance for purposes of grading, certification, and evaluation of progress (Bloom, 1974). Formative assessment is more recent. It emphasizes the role played by classroom assessment in improving the learning- teaching process and eventually, students' learning outcome systematically undertaken. It is useful for curriculum construction, teaching and learning for the purpose of improving any of these three processes (Bloom, 1974).

Assessing inquiry based instruction is an enormous and complex task (Mislevy and Baxtes, 2001). Because of this, this area of science education has not been adequately assessed. Also, Beeth, Cross, Pearl, Rino, Yagnesak and Kennedy (1999) noted that there was very little information about how to assess the science process skill that students are expected to learn through science instruction.

Assessment according to Wiggins and McTighe (2005) is the process of determining what students actually know and understand based on specific goals and criteria. Students understanding can be assessed. According to Adodo and Gbone, (2013) the nature and the extent of students' understanding of scientific concepts and phenomena are key components of science curriculum. For effectiveness of instructions to facilitate students' understanding of scientific concepts, assessment tests should be readily available for the class teachers' use. Tarber (2011) observed that a large body of outcome shows that majority of teachers do not effectively diagnose students' learning problems, especially at an early stage of students' learning process. Adodo and Gbone (2013) stated that in order to test the effectiveness of classroom instruction to facilitate students understanding of scientific concepts, assessment tests have to be readily available for use by classroom teachers. He added that for science teachers to be more effective and productive, diagnostic formative assessment approach are needed as the current assessment procedure to an in-class formative assessment used by science teachers in the standard test, which are largely paper-pencil collection of individual items with single correct answer MCQs (Multiple Choice Questions) presented without a surrounding context (Owino, Ahmed and Yungunyu, 2014). There is need for a change that will provide opportunity for teachers to develop clinical judgment about students understanding of significant ideas and processes and encourage student interaction discussion instead of measuring education progress. According to Cokadar (2012), assessment should be made in such a way that it requires explanation of the answers. He therefore suggested that teachers must consider the intuitive knowledge base that students have before coming to class, and that teachers should try to understand students' thinking of science concepts and relate their teaching to the students' knowledge.

## 2.4 Biology as a Subject in Nigerian Secondary Schools

The 9-3-4 system of education in Nigeria which focuses on self-reliance and sustainable national development is built around science and technology. Included among the basic science subjects, is biology. The study of biology is essential for the nation's scientific and technological development. It is a science subject which aims at equipping students with relevant appropriate scientific skills, competences and ability to apply scientific knowledge to every challenge of life (Egbunonu and Ugbaja, 2011).

Without sound knowledge and wholesome attitude towards biology, the much needed and vouched technological breakthrough may not be achieved. For instance, the knowledge of biology is brought to play in the areas of manufacturing and processing industries, medicine, food production and pharmaceuticals among others.

Unfortunately, research reports show that students perform poorly in biology. Okoye (2014) reported that the result of the Senior Secondary Certificate Examination (SSCE) in biology of 2013 show very poor performance. There is therefore need to improve teaching and learning of biology with the hope that performance in the different examinations will be improved. Nwagbo (2010) attributed students' poor performance in biology to a number of factors, among which are, incompetent mode of teacher's teaching of the subject, inadequate use of instructional materials and ill-equipped biology laboratories. Ogbeba (2010) stated that most teachers emphasize theory instead of practical aspects of science subjects and that most of the teachers lack adequate knowledge of the subject matter and the competence to deliver. Science is presented dogmatically in most schools as a series of disjointed facts and concepts which students find difficult to relate to the real world. Effective teaching occurs when students learn and achieve scientific goals and not just being able to repeat scientific knowledge (Omoifo, 2012).

Considering its fundamental characteristics and importance, biology is today a standard subject of instruction at all levels of our educational systems in Nigeria, from pre-primary to tertiary. It is the only core science subject at Secondary School Certificate Examination (SSCE) level, whose study is very relevant to man's successful living. Exposure to biology education offers the learners a wide range of relevance to all aspects of life. Biology is a key subject on the curriculum of Nigerian Colleges of Education under the supervision of the National Commission for Colleges of Education (NCCE). The philosophy behind the subject is to produce knowledgeable, highly motivated, professional and effective teachers of biology who will be able to develop in students, an appreciation and understanding of biological process and principles (NCCE, 2010).

Several researchers have pointed out different reasons for students' poor performance, some of which are due to the abstractness of certain aspects of biology, lack of understanding of certain biological concepts and terminologies on part of the students (Samikwo, 2013). As a result of failing experiences, some students begin to doubt their intellectual abilities and come to believe that their efforts to achieve are futile .These feelings in turn, lead to a low persistence level; they give up learning as soon as something appears to be difficult. Hence, there is a great need for students to be motivated to develop positive attitude which is crucial to performance in any subject. Cimer (2012) opined that poor attitude of students and even of teachers to biology is a destabilizing factor to successful biology development. There is a need for modern innovative teaching approaches in line with latest development in science and technology to help the conventional methods for better performance.

Practical experience is very fundamental in the biology class. Obiekwe and Nwagbo (2010) observed that most biology teachers use all the biology periods for theoretical aspect of the subject neglecting the weightier practical aspect which has potential for developing critical thinking and objective reasoning abilities in the students. Research has shown that many teachers lack the competencies, skills and creativity to organize practical classes (Ogbeba, 2010). Herrmann-Abel Flanagan and Roseman (2012) found that students have troubles understanding key biology ideas because they lack understanding of fundamental chemistry ideas. For better results at the basic education levels, teachers need to be more proactive, creative and committed. Nigerian teachers of primary and secondary school pupils have the responsibility of making a paradigm shift from being instructors, expositors, fact givers and verifiers to facilitators, stimulators, proactive and productive teachers(UNESCO, 2010).

However, despite the threat of discouraging reports of poor students' performance, influx of incompetent, half-baked and inadequate skilled graduates in the labour markets, high achievement still need to be readdressed and harnessed in the educational system. The main purpose of education is to improve students' learning achievement.

### 2.5 Some Factors Affecting academic Achievement in Biology:

#### 2.5.1 Teachers Attitude to Biology Teaching

Indeed, skills or attitudes, as determinants of behaviour and performance can be shaped by new experience often provided by activities included in training programmes (Adeyoju, 2010). The question now is - How thorough is teacher education programmes being run in the faculties and institutes of education of our various universities today? This concern is corroborated by the findings of Amadi cited by Okoye (2014) in a study on achievement of teacher education objectives. He suggested the modification of the strategies to achieve our educational objectives and the need for teacher-educators, in particular, to think about the deeper meanings of teacher preparation objectives and re-orient their methodology of teaching and training of teachers.

Assessment of teachers' attitudes, proficiency and effectiveness in the primary and post-primary institutions today suggests the abysmal state of teacher preparation in our training institutions. This by extension is responsible for the falling and failing standard of education being experienced. Of course, the causal factors range from contingency effects of external factors around the school system to the effects of the interplay of other units within the school system itself amongst other things (Oluwatimilehin, 2013). In his study, Okoye (2014) reported that, a trained teacher should be thoroughly and rigorously groomed in all techniques of teaching and all aspects of pedagogy, whether he has been on practice or not, since it is not sufficient to organize a brush up programme for a quack nurse, doctor or lawyer to make a professional out of him.

Reports from prior studies (Adeyoju, 2010; Okoye, 2014; Adedibu and Olayiwola, 2007) indicate apathy, truancy, lateness to school and other forms of poor attitude to work among teacher-trainees. In the context of science technology and mathematics (STM) education Okebukola (2005) in Adedibu and Olayiwola (2007) highlighted the features of the envisaged graduate science teacher that will emerge for service in the Nigerian secondary school system starting from 2011 vis-à-vis the present crop of teachers undergoing training in our universities. An eight point weakness was discovered which carry-over effect must be seriously addressed to avert an imminent disaster in STM education delivery. The discoveries include:

- Lack of practical skills as a result of inadequate exposure to teaching practice
- Poor classroom control and management
- Lack of in-depth subject matter knowledge
- Lack of self-reliant and entrepreneurial skills
- Inability to communicate effectively in English language
- Lack of professionalism
- Poor attitude to work and
- Poor computer skills

Meanwhile Akale (2005) in Adedibu and Olayiwola (2007) reiterated the fact that nothing is absolutely wrong with the curriculum contents for teacher preparation. The content is in the hands of teachers whose preparedness to ensure its relevance to national development, remains questionable and at best doubtful.

With the present era of science and technological revolution and advancement world over, Nigeria cannot afford to be left behind. And for her to catch up with this latest development, serious attention needed be given to the education industry and teacher education programme in particular. The reason being that the much talked about technological advancement can only directly and indirectly emanate from the classroom.

### 2.5.2 Impact of home environment on achievement

Research has clearly established that home background is very important for school achievement. Meman (2010) in his study revealed that majority of students whose parents were educated performed better in matriculation examinations as compared with those students whose parents were less educated or illiterate. Osuafor and Okonkwo (2013) supported this finding, and Meman, Mohammad and Mohammad (2010) further stated that there is a strong relationship between students' science achievement and student home background. This may be measured by the amount of books at home or speaking the language of the text at home. They explained that children from educated family have a lot of opportunities to study hard due to their access to internet, newspaper, and television. They are also taught extra lessons at home. Suman (2011) found that education and occupation of parents positively influenced the academic achievement of students. Femi and Adewale (2012) concluded in his study that educational qualification of parents and health status of students are significant factors that affect academic performance of students. Remi and Adewale (2012); Osuafor and Okonkwo (2013) showed that home background measured an index summarizing students` economic, social and cultural status as some of the most powerful factors influencing performance. Akinsanya. Ajayi, and Shalon (2014) showed that many disadvantaged students spend less time studying science in school than their peers who are more advantaged. Many of them end up in schools where there are very low academic options and they do not have the opportunity to take science courses. Femi (2013) therefore advised that learning time at school should be considered when designing policies to improve performance among disadvantaged students.

Interest is another factor that can influence performance in science. According to Ben (2013) interest is a fundamental factor necessary for an effective learning. Ben showed that interest in science appear to be influenced by student background. Students with a more advantage socio-economic background or those who had a parent in a science related career are likely to show general interest in science and to identify how science may be useful to them in future.

### 2.5.3 Teacher's Quality

Dahar and Faize (2011) reported that different studies show that the most important resource input in the school that predicts students' academic achievement is Teacher`s Quality. The five indicators of teacher quality are academic qualification, professional qualification, in-service refresher courses and trainings, teacher experience and teacher salary. Auwalu, Mohd and Mohammad (2012) stated that many inexperienced teachers teach science in abstraction, thereby making science lessons boring and the students finding it difficult to grasp some scientific concepts, skills and principles. Dahar, Dahar, Dahar and Faize (2011) found that most of the science teachers are not professionally trained; as a result of this an engineer is recruited to teach mathematics, physics, chemistry and even biology rather than specialists that are trained teach the subjects. Omoregbe and Ewansiha (2013) stated that poor quality of science teacher is another factor that influences students' performance. They added that the teachers' qualification, knowledge of the subject matter, competence and skills, and commitment to work influence teaching and learning process, and so, affect the performance of the students. Different factors have been given by different researchers for the poor academic performance of students in science, particularly biology. Auwalu, Mohd and Mohammad (2014) observed that poor performance in science is caused by the poor quality of science teachers, overcrowded classrooms, and lack of suitable and adequate science equipment among others. According to them, students perform poorly in biology because the biology classes are usually too large and heterogeneous in terms of ability level. Osuafor and Okonkwo (2013) in their study found that the possible factors responsible for poor performance in biology include lack of financial support, lack of equipped libraries, lack of laboratories, and biology textbooks, and poor method of teaching and assessing biology. Owino, Ahmed and Yungunyu, 2014) attached the problem of poor performance to inadequate supply of teaching and learning resources such as chemicals, charts, apparatus, models, local specimens, laboratories, textbooks, libraries, lead to poor performance in biology.

**2.5.4 Gender Stereotyping**

Gender differences in average level of achievement are usually small when compared with other basic skills in some subjects. Gender awareness is influenced by the distribution of male and female students (Oludipe, 2012). Ezeudu and Obi (2013) in their study found that males achieved more than the females in Chemistry. However, Brewness and Tanner (2010) found no gap between males and females in the understanding of physics concepts. Laurer, Offerdau, Christensen and Montpleisir (2013) found that no achievement gap existed between men and women in basic science. Gender according to Yang, Liu, Ge, Chen and Zhao (2012) refers to the social attributes and opportunities associated with being male and female and the relationship between women and men. Therefore there is the need to promote the teaching and learning of biology in schools especially among female students.

Nwogu (2013) indicated that gender and the interaction of gender and school location were significant factors in students' conceptual understanding of force and motion. Although female students tend to be superior to their male counterparts in developing conceptual understanding of force and motion, this relative superiority was not consistent across school locations. He recommended that physics teachers should be more gender sensitive in their pedagogical approaches as well as in the planning of physics curriculum. This recommendation could be equally applied to biology.

## 2.6 Biochemical Topics/Chemical concepts and Conceptual Understanding

Biology is the scientific study of life and life can be recognized by what living things do. Biologists study life (natural system) and some concepts of chemistry and physics also apply to biology. The basic concepts of chemistry are referred to in this study as chemical concepts.

Biochemistry is the study of the chemical processes within and related to cells of living organisms. The cells are building blocks by which organisms or living systems are made. Biochemistry has also been described as the science, which studies the chemical composition of cells, the chemical reactions in the cells and processes they go through. Biochemistry is therefore the study of cells and organisms and the molecules that take part in their chemical reactions. Biochemistry is absolutely necessary for all life sciences. It is important for the study of genetics, physiology, immunology, pharmacology, pathology, microbiology, zoology, botany and medicine.

Photosynthesis and respiration are very important processes in life. They are some of the biochemical topics in the senior secondary school curriculum. Ahiakwo and Uti (2014) stated that photosynthesis and respiration are very important for the understanding of movement of energy and raw materials in the ecosystem.

Cokadar (2012) defines respiration as the process by which organisms obtain energy from organic substances in aerobic and anaerobic conditions.

The summary of the reaction is given below:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6H_20 + 6CO_2 + 38\ ATP$$

Glucose Oxygen Water Carbon Energy

(IV) Oxide

Respiration is one of the vital processes of living things. It is one of the characteristics of living organisms. Because of its importance students at all levels learn scientific information and construct their cognitive structures about the concept of respiration. Respiration is an oxidative reaction that provides energy required to do work in plants and animals. Cimer (2012) reported that students experience difficulties in learning and constructing their cognitive structures about respiration. This is because according to Tasdemir and Demirizas (2010), the concept of respiration is a complex process with numerous sub-concepts and each of these concepts are linked with one another to form a much more complex structure. Due to its complex and abstract nature, students fail to form their cognitive structures and cannot establish links with their daily lives which is related to this complex structure of respiration. Sinan and Karadeniz (2010) stated that, that is why students fail to draw a full picture of the subject in their minds.

Cognitive structure is a structure that represents the relationship of concepts in the students long – term memory that is based on assumption. Teachers should find out the students prior knowledge and help to carry out research on students' conceptual changes to help their works. Conceptual knowledge is very important for the learning of respiration. According to Kurt, Ekiki and Aktas (2013), conceptual knowledge is not only to know the name or definition of a concept, but also to be able to see the transitions and relationship between concepts. Students cannot learn respiration without the understanding of some linking chemical concepts. These chemical concepts are prerequisite for the learning and understanding of respiration.

Ahiakwo and Uti (2014) defined photosynthesis as the process that takes place in green parts of plants whereby carbon (IV) oxide ($CO_2$) gas reacts with water ($H_2O$) in the presence of chlorophyll, enzymes and solar energy to produce carbohydrate and oxygen ($O_2$). The equation below summarized the overall processes:

$$6CO_2 + 12H_2O + \text{Light} \longrightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$$

Photosynthesis is one of the most important processes in plants and it is one of the most important topics of biology. Photosynthesis as a fundamental process for life on earth has long been a core part of the school biology curriculum (Matthew, 2009). According to Cokadar (2012), photosynthesis is one of the main topics about which students experience learning difficulties. Learning photosynthesis is difficult because it involves complex transformation and biochemical processes. According to Kurt, Ekiki, Aktas and Aksu (2013), other subjects like physiology biochemistry, ecology transformation of energy, autotrophic nutrition and transport system in plants are also complex topics. Concepts of the process of photosynthesis are most of the time misunderstood by students. As a result of this, students cannot fully construct their cognitive structure, when learning about life. Prior knowledge is important for the learning and understanding of photosynthesis because of its nature and so, different methods are used to determine conceptual learning. More commonly used techniques are the alternative measurement and evaluation techniques. The technique determines students' knowledge and the relations that the students establish between concepts, students' cognitive structure and if they were able to link their existing knowledge with the new information (Novak, 2011).

Chemical concepts are pre-requisites for understanding biochemical topics and other science related courses. Rytkonen, Parpala, Lindblom, Virtanen and Postareff (2012), opined that gaining complete knowledge of the concepts of chemistry in the area of structure of matter is important for further course work in all sciences. This makes chemistry to be generally viewed as a central science. They stressed that before the beginning of students coursework in their prospective majors in science, apart from chemistry, they should take courses in chemistry. They concluded that chemistry plays the role of gate-keeper for other sciences.

Conceptual understanding of science involves the understanding of both simple (oxidation) and complex (redox reactions) concepts, thus making meaning out of the concept (Nieswandt, 2007). According to her, the basic concepts that should be taught in the ninth grade chemistry school curriculum for conceptual understanding are: matter, physical and chemical properties, chemical reactions, conservation of mass, redox reactions, particulate models, atoms and molecules. When teaching these concepts, their relationships and interactions are discussed relating them to everyday life phenomenon (such as burning of candle, tarnishing of silver cutlery, rusting of nail) and topics in the area of science and technology (such as greenhouse effects, and waste management and recycling).

The knowledge of biochemical concept requires the knowledge of chemical concept (Beskeni, Yusuf, Awang, Ranjha, 2011). They investigated the effects of prior knowledge on the understanding of difficult chemistry concepts at secondary school level and found prior knowledge help in the understanding of difficult chemistry concepts. Therefore for effective teaching and learning of chemistry, prior knowledge must be considered in any classroom situation. Also Villafane, Loertscher, Minderhout, Lewis (2011) supported this statement and said that previously learnt concepts of general biology and chemistry have to be applied when learning biochemistry. For meaningful learning to take place there must be relevant concepts available within the cognitive structure which can be linked with new material. Khan (2011) stated that concept understanding level of class ix students in chemistry was low. Bone and Reid (2010), found that non-completion of the organic chemistry prerequisite course by some of the students, before the biochemistry course likely makes them to withdraw from the course while students who completed the prerequisite course were not likely to withdraw. Bone and Reid, (2011) in their research found that students who completed biology and chemistry at the senior high school level performed better than those who did not complete biology and chemistry in first year chemistry. Cimer (2012) also found that students' had difficulties in learning matter cycles, endocrine system, aerobic respiration, cell division, genes and chromosome because of the nature of the topics, teacher's style of teaching students, learning and studying habits, students' negative feelings and attitudes towards the topics and lack of resources.

## 2.7 Challenges of Teaching Biochemical Topics

Mhlamvu (2008) said one the basic problems of teaching biochemistry and biophysics is that they involve the understanding of concepts that are abstract. In biology some of the biochemical topics that are taught include structures and functions of proteins, membranes, and electron transport among others. Bhinyo, Pintip and Namkang (2008) observed that since the main basic concepts were not understood by students, they could not apply their basic knowledge to answer simple questions in the topic of photosynthesis.

Aluko (2009) identified some of the problems that resulted to the persistent poor performance of students in chemistry: as ineffective teaching methods, lack of infrastructures, lack of professionally qualified teachers, lack of technicians/laboratory attendants, lack of organized strategies for problem solving, poor reasoning and poor mathematical background. Edomwonyi-Otu and Ayaa (2011) found that teachers and students have negative attitudes towards chemistry; lack of enough time allocated to each lesson and periods to cover the syllabus; inadequate laboratory involvement of students to practical lessons; and the desire to pass by examination malpractice as some factors that give rise to students` poor performance in Chemistry. According to Menalanga and Awelani (2014) the main contributing factors to low learning and learning outcome are, poor conditions of learning environment; shortage of essential instructional materials and textbooks, outdated curricula; poor teaching strategies; most teachers teaching STM related subjects without appropriate qualifications. Other factors according to them, are lack of adequate resources, inadequacy of computers in the schools and parents appearing too busy to look into students school work at home (Auwalu, Mohd, and Mohammad, 2014; Obomanu and Adaramola, 2011). The researcher believes that academic achievement in biology can be achieved by providing relevant text books, new modern libraries with computers, employing regular reading habits by students, maximum number of students per class should be 40 – 50, providing zoological and botanical gardens in secondary schools and government getting involved in financing projects that will motivate students to learn biology

Muwanga, (2007) said one of the challenges of teaching biochemistry is that learning involves understanding of concepts which are abstract. The abstract nature of a lot of biochemistry topics that would lay foundation to the understanding of photosynthesis, respiration, organic compounds- carbohydrate, protein and fats and enzymes pose challenges to teachers and so they avoid them. The object and processes are therefore not presented in a way that would make learning understandable and exciting to the students when teaching. Nnaji (2007) also observed that many chemistry teachers find some topics in the chemistry curriculum difficult to teach because they are abstract.

## 2.8 The Place of Integrated Science in the Nigerian Educational System.

Integrated science is offered at the junior secondary school level and it provides students with the sound basic background for further science education. Integrated science is the prerequisite for studying the core science subject (biology, chemistry and physics). Students have to be grounded in integrated science for them to have interest in taking their core science subjects (Oludipe, 2012). Due to the dwindling number of students that seek admission into the tertiary institutions for science courses, researchers in science education embarked on a series of studies to find out why many students prefer to offer arts subjects than science, and have found out that the problem is from the Junior Secondary School (JSS) level.

In the junior secondary school curriculum of Nigeria, various chemical concepts under matter and its properties appear in the integrated science programme. Some of these concepts are atoms, elements, compounds, physical and chemical change, valency, chemical symbols, simple chemical equations. The concept of chemical reactions for instance in junior secondary one in the topic of matter and properties of matter, physical and chemical properties found in the Nigeria Integrated Science Project (NISP) and Nigeria Secondary School Science Project (NSSSP) which was developed by the defunct Comparative Education Studies and Adaptation Centre (CESAC).

Chemical reaction is a process in which the physical and chemical properties of the original substances change to new substances with different physical and chemical properties. A substance that enters a reaction is called reactant and a substance that is produced is called a product, which could be in the form of elements, compounds, chemical symbols and formula, simple chemical reaction.

Biological education literature is replete with studies concerning students' alternative conception about major topics such as photosynthesis, respiration, natural evaluation and diffusion and osmosis. Students understanding of diffusion and osmosis in biology education have received much attention (Kose, 2007; Kornk and Kihe, 2008). Biochemistry, chemical concepts, principles, theories, and laws are used to explain issues that associated with biological phenomenon. Since biology studies plants and animals and these are made up of chemical compounds, it is important to note the chemical concepts that are associated with the processes are taught. The link between biology and chemistry make it important for a curriculum to be drawn in such a way that chemistry is married to biology to help students to understand biochemical concepts like photosynthesis, respiration, diffusion and osmosis.

Chemical processes are the bases for gaining knowledge into what happens during photosynthesis and respiration (Ahiakwo and Uti, 2014)

Findings from their work revealed that students have several alternative conceptions and difficulties in diffusion and osmosis. Diffusion and osmosis are related to many aspects of living organisms. They serves as key concepts for understanding important life process and students encounter them in daily life, because of this, there concepts needs to be learnt and taught well. Diffusion and osmosis are not only related to biology, but are also related to chemical phenomena like solution, solving, dissolution and semi-permeability. To be a successful student, student must be able to make connection between the new information and their existing knowledge (prior knowledge, assumed knowledge).

For these reasons, biology teachers are expected by the researcher to teach chemical concepts before teaching most of biochemical topics as the teaching of the chemical topics will lay foundation for the learning and understanding of the biochemical topics; so that they can apply them to their daily life (Muraya and Kinamo, 2011). Based on foregoing, the researcher decided to carry out this study to find out the effect of level of chemical concepts understanding on students' achievement in biochemical topics.

## 2.9 Past Studies on Conceptual Achievement in Science

Cimer (2010) found that students had difficulties learning five topics: matter cycle, endocrine system and hormones, aerobic respiration, cell division and genes and chromosomes in Turkey. The main reasons for their learning difficulties were the nature of the topics, teachers' style of teaching, students' learning and studying habits, students' negative feelings and attitude towards the towards the topics and lack of resources. The participants of the study suggested that to overcome these difficulties and make biology more effective; Biology should be taught with visual materials; teachers should teach through practical work; and biology curriculum content should be reduced. They further suggested that various study techniques should be used, and that Biology should be taught through connecting the topics with daily life.

Ahiakwo and Uti (2014) studied students, chemical knowledge in photosynthesis and respiration in Port Harcourt metropolis Rivers State, Nigeria. Their findings show that students' answers to questions contained deficient of relevant chemistry contents of photosynthesis and respiration reactions. Students' answers also lacked integration. In conclusion, the study revealed students' deficiency in related chemical knowledge required to thoroughly understand photosynthesis and respiration processes. The students were unable to integrate knowledge which is required to show understanding in photosynthesis and respiration.

Cokadar (2012) studied Photosynthesis and Respiration processes: Prospective Teachers' conceptual levels. The purpose of the study was to determine and compare prospective teachers' conceptions of photosynthesis and respiration processes that are important subjects in science and technology courses. Sample consisted of 90 Senior Students from the Elementary Science Department and 62 sophomore students from Primary Education Department in the Faculty of Education, Pamukkale University, Denzli, Turkey. The findings showed that learning outcome of the education period met only limited success because the of the low prospective students' preconceptions about the functions and educational materials. The inadequate subject knowledge of prospective teachers suggests that the undergraduate chemistry and biology courses may not sufficiently equip them with a strong foundation in the discipline for elementary science curriculum. Majority of the prospective teachers did not have an accurate understanding of the concepts of photosynthesis and respiration. The recommendation was that teacher should help students to make connection between their old conceptions and the new, scientifically acceptable connections being introduced.

Mhlamv (2011) investigated possible reason for the high failure rate in biology under the topic photosynthesis and the results showed that students performed poorly in lower and higher order questions. Learners who have chosen career that require biology did better than their peers who did not. The study showed the girls performed as well as the boys. It was also shown that language was a major barrier in expressing the learners' ideas.

Kakakuyu (2010) examined the effect of concept mapping on attitude and achievement in physics course and concluded that the use of concept mapping was effective in improving students' achievement, but ineffective in enhancing students attitude towards physics. Ceylan and Geban (2010) worked on promoting conceptual change in chemical and energy concepts through the conceptual change oriented instruction. Sample of 61 $10^{th}$ grade students (33 males and 28 females) was used for the study. The results revealed that Conceptual Change oriented Instruction Design through demonstration (CCID) caused a significantly better acquisition of the scientific concepts related to chemical reactions and energy concepts than Traditional Designed Chemistry Instruction (TDCI). There was a significant difference between post-test mean score of students taught with CCID than those taught with TDCI with respect to their attitude toward chemistry in favour of the group exposed to CCID but no significant difference between males and females students with respect to their attitude towards chemistry.

Igwebuike (2013) found out that low achievers in integrated science taught using conceptual change pedagogy will achieve significantly better than their counterpart taught using the expository study approach. According to him, conceptual change pedagogy is superior to expository strategy in enhancing achievements, developing effective components of learning. Oludipe (2012) studied the influence of gender on junior secondary students' academic achievement in basic science using co-operative learning teaching strategy and found that there was a significant difference between the academic achievement of male and female students at the pre-test and post-test levels, respectively.

Khan (2011) studied the existing level of understanding of concepts in the subject among class IX students to explore the pre-test level of concept formation during teaching of chemistry to class IX students. The result of the study showed that the existing level of understanding of concepts in the subject of chemistry is low and this condition impacted on the ability of the students to grasp the new topics. Aldahmash (2009) showed that students' understanding on organic reaction mechanism depends on their spatial ability based on the research study on the difference between kinetic (computer animated) and static visuals in the ability of college students to understand an organic reaction mechanism in chemistry.

Ezendu and Obi (2013) studied the effect of location on gender achievement in chemistry and reported that the male students achieved significantly more than the females irrespective of the location of their schools. It was also found that family structure and parents' occupation and educational level of parents had no significant influence on students' achievement in senior secondary school biology (Osuafor and Okonkwo, 2013). This finding has opposed many other research results that have proved otherwise.

Muzammila, Johan and Murad (2014) explored conceptual difficulties of secondary school students to understand the concept of electrochemistry like redox reaction, galvanometer and electrolytic cells with 114 elementary students of IX classes. The results showed that 67% of the concept-based items designed in electrochemistry were difficult to understand by Secondary School Students, poor background of chemical knowledge, absence of teaching aids, and language difficulty. Ikitde and Edet (2013) studied the influence of learning and teaching strategies on students' achievement in biology with 2440 senior secondary two (SS II) biology students made up of 136 females and 104 males. The purpose was to investigate the effect of learning styles (active/reflective, sensing/intuitive, visual/verbal, and sequential/global) and teaching strategies (guided inquiry/demonstration and lecture) on students' achievement in biology. Their findings revealed that:

- Students with sensing/intuitive learning styles performed better when taught with guided – inquiry teaching strategy.
- Demonstration teaching method is the most effective strategy in enhancing the achievement of students with sequential/global learning style.
- Lecture method is most effective for students with visual verbal learning style.
- There is no significant effect of gender on students' achievement when taught with guided-inquiry, demonstration, and lecture teaching strategies based on learning style.

Students under multimedia instruction performed better than the conventional teaching group method and students in conventional teaching method had better retention than other groups (Gambari, Yaki, Gana and Ughavwa, 2014) from study of the effects of video-based multimedia instruction on secondary school students' achievement and retention in biology in Nigeria. In summary therefore, at the individual level biology achievement was associated to approach to learning, prior-knowledge. Furthermore, at the class level, academic achievement was only associated with teachers' approaches to teaching (not directly) but through students' approach to learning (Nunez, Vallejo, Posario, Tuero and Valle, 2014).

## 2.10 Appraisal of Reviewed literature

The review carried out shows that the problems of students' achievement in biology are enormous. The literature cited above revealed several specific factors militating against the effectiveness of biology teaching/learning towards conceptual understanding at secondary school level. From the literature review, the roles of student and contextual variables in students' achievement are inconclusive. The review revealed that chemical and biochemical concepts are difficult to learn and understand as widely reported. This according to some of the researchers may be attributed to the fact that the concepts are abstract and student do easily not understand them and cannot relate them to their daily life (Tasdemir and Demirizas, 2010).

The review also shows that performance of students in biology is poor and that prior knowledge has tremendous implication in the teaching and learning of biochemistry (biochemical concepts); prior knowledge for biology and chemistry must be considered in any classroom situation. It was found that students who are likely to withdraw from biochemistry course are those who did not complete the prerequisite organic chemistry course, before the biochemistry course. The learning of biochemical topics depends on the application of prior knowledge of concepts of general chemistry and biology and that for any meaningful learning to take place, there must be relevant concepts which are available within the cognitive structure which can be linked with the new material.

Teaching in areas like biochemistry and biophysics involve the understanding of abstract objects, concepts and processes that cannot be seen or experienced. So students do not understand the main concepts and therefore would not be able to apply basic knowledge to answer simple questions in topics such as photosynthesis. It was also found out that students had difficulty in learning matter, aerobic respiration, cell division, endocrine system, genes and chromosomes. One of the main reasons for this difficulty is the nature of the topics (concepts that cannot be seen or experienced). Because of this, students have difficulty in understanding the concepts. It was also found that concept understanding level of students in senior secondary school chemistry is low.

From this review, it is the researcher`s opinion that chemical concepts understanding aid the understanding of biochemical topics. Therefore, for better enhanced performance in biochemical topics, the teaching of chemical concepts should precede the teaching of biochemical topics.

From the review, there was no study available to the researcher on the effect of understanding level of chemical concepts chosen for this study on achievement. Therefore, the researcher tried to find out the effects of chemical concept (elements, compounds, chemical symbols, formulae, simple chemical equation, physical and chemical changes) understanding level on students' achievement of Biochemical topics (photosynthesis, cellular respiration, carbohydrates, protein, fats and oil, and enzymes).

# CHAPTER THREE

## RESEARCH METHODOLOGY AND PROCEDURE

This chapter focuses on the research procedures adopted for the study as presented under the following sub-headings:

- Research design
- Population of the study
- Sample and Sampling technique
- Instrumentation
  - i) Development of instrument
  - ii) Validity of instrument
  - iii) Reliability of instrument

  Administration of instrument or method of data collection

  Control of external variables
- Method of data analysis

### 3.1 Research Design

The study adopted a mixed method research approach of quantitative and qualitative nature to achieve the objectives of the study.

#### 3.1.1 Quantitative Research Design

The research design that was used for the quantitative research was quasi experimental non-randomized pre-test post-test control group design.

In quasi experimental design intact groups or classes are used and members are not assigned to the groups and classes randomly (Ary, Jacobs, Sorensen (2010).The design takes this form;

Pretest Treatment Posttest

Experimental Group

$O_1$ $X_1$ $O_2$

-------------------------------------------------------------------------------------------Control

Group

$O_3$ $X_2$ $O_4$

The broken line indicates that there was no randomization. Three intact classes where used.

$O_1$ – Pre-test, Experimental Group: (BAT)

$O_2$ – Post-test, Experimental group: Biology Achievement Test (BAT)

$O_3$ – Pre-test, Control Group: (BAT)

$O_4$ – Post-test, Control group: Biology Achievement Test (BAT)

$X_1$ – Experimental Group: They were taught Chemical Concepts (TOSUCC) (for four (4) weeks).

$X_2$ – Control Group: No Treatment.

### 3.1.2 **Qualitative Research Design**

This study adopted the case study research design. The design is chosen as it offers richness and depth of information not usually offered by other methods. The chosen design was Embedded Design (Garacelli and Greene, 1997). The design was chosen based on its power for triangulation and complementary purposes to the quantitative data generated for this study. The design is as represented below:

**Quan** → **Interpretation** ← **QUAL**

**Data and Results** **Data and Results**

**Dependent Variables**

The dependent variable used of this study was students' achievement in biochemical topics.

**Independent Variable**

The independent variable of the study was students' chemical concept understanding level.

## 3.2 Population of the Study

The population of this study consisted of all male and female senior secondary II (SS II) students in the twenty five LGA of Delta State. In figures, the total population was 72,876 students with an average of 4,896 at the research grade in each senatorial zone of the State.

## 3.3 Sample and Sampling Technique

The research sample consisted of 592 (five hundred and ninety two) senior secondary II students drawn from six public co-educational secondary school randomly sampled from the three senatorial zones of Delta State of Nigeria. The schools were further randomly assigned as follows: Three (3) schools were for experimental groups and the other three (3) schools for control group.

Student samples for the study were taken as they were in their classes. Therefore, three intact classes of 104, 96 and 103 students respectively were used for experimental groups and three intact classes of 97 (ninety seven), 98 (ninety eight), and 94 (ninety four) students respectively were also used for the control groups.

The external variables identified for the study were gender and school location; they were built into the test instruments. Analysis of the sample used in the study showed that there were 263 (two hundred and sixty three) females and 329 (three hundred and twenty-nine) males. In terms of school location, the sample was made of 412 (four hundred and twelve) students in urban and 180 (one hundred and eighty) students in rural areas.

### 3.4 Instrumentation

Two teacher-made tests instruments were used for the quantitative data collection and a semi-structured interview schedule was also used for qualitative data gathering in this study. The quantitative data instruments are:

1 The Test Of Students' Understanding of Chemical Concepts (TOSUCC), Appendix III based on physical and chemical changes, elements, compounds and mixtures, chemical symbols, valency, chemical formula, simple chemical equation.

2 Biology Achievement Tests (BAT), Appendix IV on Biochemical topics which included photosynthesis, respiration, diffusion and osmosis, carbohydrate, proteins, fats, and enzymes.

For qualitative data collection purposes, a purposive sampling technique was adopted to select two biology teachers and four of their senior secondary school II students for in-depth face-to-face individual interviews, Appendix xiv.

#### 3.4.1 Test of Students' Understanding of Chemical Concepts (TOSUCC)

The objective of this test was to find out the chemical concept understanding level of students and to find out how understanding of chemical concept affects understanding of biochemical topics. It was a teacher made test, which was content specific and made up of 5 (five) essay and 20 (twenty) short structured test items, which covered the chemical concepts mentioned above. For the construction of the test, a table of specification was made using chemical concepts physical and chemical changes, elements, compounds and mixtures, chemical symbols, valency, chemical formula, chemical equation and was shown to the supervisor for necessary correction. These concepts were part of integrated science course as contained in the junior secondary school (JSS) syllabus produced by the government give students at this level a good fundamental knowledge of science and scientific concepts.

**Table 3.1: Research Table of Specification for Test Items for Chemical Concepts**

| | **Knowledge** | **Comprehension** | **Application** | **Total** |
|---|---|---|---|---|
| Matter | 2 | 2 | 1 | 5 |
| Physical/Chemical changes | 1 | 2 | 2 | 5 |
| Element, compound and Mixture | 2 | 1 | 2 | 5 |
| Chemical Symbol/Valency | 2 | 2 | 1 | 5 |
| Chemical Formula/Equation | 1 | 2 | 2 | 5 |
| **Total** | | | | **25** |

**Table 3.2: Research Table of Specification for Test Items for Biochemical Topics**

| | Knowledge | Comprehension | Application | Total |
|---|---|---|---|---|
| Diffusion/ Osmosis | 1 | 2 | 2 | 5 |
| Respiration | 2 | 1 | 2 | 5 |
| Photosynthesis | 2 | 2 | 1 | 5 |
| Enzymes | 1 | 1 | 2 | 5 |
| Carbohydrate/ Protein/Fat | 2 | 2 | 1 | 5 |
| Total | | | | 25 |

The test items covered the first three levels of Bloom's Taxonomy. The first three levels where taken because the test was to measure understanding, knowledge, comprehension, and application levels. The researcher answered the questions in the memorandum the same way she expected the students to answer them and they were given to the supervisor for scrutiny. After the approval of the test instrument by the supervisor, the test items were typed and printed making sure that the prints were clear and readable, with complete pages in the correct order. A marking scheme (Appendices V and VI) was also prepared by the researcher with approval by the supervisor for the study.

### 3.4.2 Validity of the Instruments

Validity was defined on the extent to which an instrument measured what it claimed to measure (Ary, Jacobs, and Sorensen, 2010). The drafts of the test items for both cognitive tests and interview schedule were given to six experienced integrated science, chemistry and biology teachers for content validation based on the research tables of specification shown above. This was for the Validators check for necessary corrections, amendment for content relevance, correctness and clarity. Some items were deleted and some others were modified on the consensus recommendations of the Validators and the amended versions were sent to the supervisor for approval in line with content, predictive and face validity requirements of the items.

### 3.4.3 Reliability of the Instruments (TOSUCC)

Reliability of a measuring instrument is the degree of consistency with which the instrument can produce stable results or measures whatever it is expected to measure (Ary Jacobs, and Sorensen, 2010). The test instrument were administered to SS2 (Senior Secondary Two) students of college of Education, Model Secondary School, Agbor in Ika Local Government Area of Delta State, Nigeria, to determine the reliability of the instrument in a pilot study. This school was not used in the main research study. The cognitive tests, Test of Students' Understanding of Chemical Concepts (TOSUCC) and Biology Achievement Test (BAT) were subjected to reliability tests using Kuder-Richardson formula 20 (K-R20) with data generated from the pilot study.

Kuder-Richardson formula 20 (K-R20) was used to calculate the reliability coefficient of the tests. Kuder Richardson formula was used because it is widely used to determine homogeneity or internal consistency. Ary, Jacobs and Sorensen (2010), said that the best probably known index of homogeneity (internal consistency) is the Kuder Richardson formula 20 (K-R20); which is based on the proportion of correct or incorrect responses to each of the items on a test and variance of the total scores:

$$r_{xx} = k - 1\left(\frac{S_x^2 - \sum pq}{S_x^2}\right)$$

Where;

$r_{xx}$ = reliability coefficient of the whole test

$S_x^2$ = variance of score on the total test

$K$ = number of items on the test

$P$ = proportion of correct responses on a single item

$q$ = proportion of incorrect responses on the same item

The product pq was computed for each item and the products are summed over all items to give $\sum$pq.

The internal consistency reliability coefficient was calculated to 0.76 for Test of Students' Understanding of Chemical Concepts (TOSUCC) and 0.74 was calculated for Biology Achievement Test (BAT).

### 3.5 Administration of Test Instruments

After the permission of the principals, students were given the consent form to fill out. Before the administration of the instrument, the research assistants used for the study told the students the purpose and importance of the tests and encourage students to complete it to the best of their ability. The researcher and the research assistants administered a cognitive pre-test on the students and then carried out the intervention of specially teaching the selected relevant chemical concepts as a deliberate approach for foundational conceptual understanding for four weeks of two teaching periods each. The chosen topics were physical and chemical change, elements, compounds, mixtures, valency, chemical symbol, chemical formula, simple equation, atomic structure using a tailor-made lesson plans on Chemical Concepts (Appendix I). Chemical concepts were taught in the first two weeks of the intervention, followed by teaching the same experimental group members the same biochemical topics in the last two weeks of the intervention periods as taught to the control group who were taught for four straight weeks but not given any special teaching on chemical concepts. The biochemical topics taught to both groups were photosynthesis, respiration, diffusion and osmosis, carbohydrates, proteins, fats and enzymes based on the Lesson plans on Biochemical concepts or topics (Appendix II). The post-test was administered by the researcher with the help of the research assistants at the end of the four week-intervention period.

As part of mixed method approach adopted in this study, a qualitative research that explores for in-depth understanding of phenomena/events in order to advance reasons for observations made was used. This was by making use of unstructured data collected with unstructured interview questions (Appendix xiv). The researcher with the assistance of two research assistants trained for the purpose of this study interviewed each of the two teacher- and four student-respondents for a period of between ten to twenty minutes. The research assistants were trained by the researcher based on the Training Package for Research Assistants (Appendix XII) developed by the researcher and scrutinized by the study supervisor. The interviews were tape recorded with the permission of the respondents. The researcher also took notes while conducting the interviews. The data collected from the respondents were then transcribed into field notes.

### 3.6 Method of Data Analysis

This study adopted a mixed method approach and designs. The data generated have then been analyzed in two phases and the basis of quantitative and qualitative data analyses.

### 3.6.1 Method of Data Analysis of quantitatively generated data

Some Descriptive Statistics involving frequency and mean, in addition to T-test of Independent Sample test and Analysis of Covariance (ANCOVA) were used to analyze the quantitative data generated for this study. ANCOVA controls for the relationship between the pretest and the outcome measures thereby reducing error variance and increasing statistical power (Knapp and Schafeur, 2009). ANCOVA and interaction graphs were specifically used to test hypotheses three and four. Using the means and standard deviations of the experimental and control samples the effect size Cohen`s d (Cohen, 1988; Baguley, 2009) was further computed to confirm the effect of the intervention approach of the study and reported in Chapter 4..

### 3.6.2 Method of Data Analysis of qualitatively generated data

The method adopted for data analysis was content analysis of interview responses. This was done following these procedures:

- Copies of the entire transcripts were read through and brief notes were made about the information gathered.
- The transcripts were typed using a word processor and the relevant notes made while reading through the highlighted words with codes. The original copies of the transcripts were kept in a file.
- From the highlighted information categories and sub-categories were identified as themes and sub-themes.
- The transcripts were reunited ensuring proper categorization had been done and interpretations for meaning were carried out.

# CHAPTER FOUR

# DATA ANALYSIS, RESULTS AND DISCUSSIONS

The present study investigated the effects of chemical concepts understanding level on students' achievements in biochemical topics in biology among senior secondary school students in Delta State. The quantitative data collected for the research were analyzed to test the four hypotheses raised at a 0.05 level of significance. Hypothesis one ($Ho_1$) was tested using the t-test of Independent Sample while hypothesis two ($Ho_2$), three ($Ho_3$), and four ($Ho_4$) were tested using the Analysis of Covariance (ANCOVA) and interaction plotted graphs.

The following sequence was followed in analyzing the data

1. Descriptive statistics on group, gender and school location.
2. T-test of Independent Sample test was used to answer research hypotheses one.
3. Analysis of Covariance (ANCOVA) was used to test hypothesis two.
4. ANCOVA and interaction graphs were used to test hypotheses three and four.

## 4.1 Descriptive Statistics on Group, Gender and Location

**Table 4.1: Distribution of Respondents by Group**

| | | **Frequency** | **Percent** |
|---|---|---|---|
| Valid | Control | 289 | 48.8 |
| | Experimental | 303 | 51.2 |
| | Total | 592 | 100.0 |

Table 4.1 shows the frequency of control group as 239 (48.80%) and experimental group 303 (51.2%). This slight difference in favour of the experimental group student sample can be the other way round since there was no randomization.

**Table 4.2: Distribution of Respondents by Gender**

| | | Frequency | Percent |
|---|---|---|---|
| Valid | Female | 263 | 44.4 |
| | Male | 329 | 55.6 |
| | Total | 592 | 100.0 |

Table 4.2 shows frequency of females as 263 (44.4%) and males as 329 (55.6). No randomization was involved in sampling student respondents; rather the intact classes were used. However, the higher percentage of male students in Table 4.2 would imply that more male than female students take biology as a school subject.

**Table 4.3: Distribution of Respondents by School Location**

| | | Frequency | Percent |
|---|---|---|---|
| Valid | Urban | 412 | 69.6 |
| | Rural | 180 | 30.4 |
| | Total | 592 | 100.0 |

Table 4.3 shows an urban frequency of as 412 (69.6%) and rural frequency as 180 (30.4). This table is a proof of higher student density in urban schools with large class sizes in most cases. It is a resultant effect of higher population density of people in urban areas for more and higher job opportunities and socio-economic provisions.

### 4.2.1 Test of Hypothesis One ($Ho_1$)

There is no statistically significant difference in students understanding of chemical when exposed to instructions on chemical concepts.

**Table 4.4: t-test of Independent Samples in Pre-test Scores on Chemical Concepts**

| | **Group** | **N** | **Mean** | **Std. Deviation** | **t** | **Sig (2-tailed) (*P*)** |
|---|---|---|---|---|---|---|
| PRE-TEST | Control | 289 | 20.94 (46.50%) | 3.09 | -2.25 | 0.822 |
| | Experimental | 303 | 20.54 (45.60%) | 3.08 | | |

$\alpha = 0.05$

Table 4.4 shows a t-test calculated value of -2.25 and a *P* value of 0.822. Testing at an alpha level of 0.05, the P value is greater than the alpha level. It shows that there is no significant difference between the two groups at the Pre-tests stage. The standard deviation values of 3.09 and 3.08 for control and experimental groups respectively at the pretest level further shows no significant difference between the groups. Percentage of the mean scores of the respondents was used to indicate their level of understanding. Thus, the mean score of less than 50% and more than 50% is considered as indicative of low and high level of understanding of chemical concepts respectively. The mean scores for the control group 20.94 (46.5%) and experimental group 20.54 (45.60%) are low. Therefore, the students' chemical concept understanding level is low.

**Table 4.5: t-test of Independent Samples in Post-test Scores on Chemical Concept**

| | Group | N | Mean | Std. Deviation | t | Sig (2-tailed) (P) |
|---|---|---|---|---|---|---|
| POST-TEST (TOSUCC) | Control | 289 | 25.94 | 3.60 | -6.838 | 0.000 |
| | Experimental | 303 | 27.93 | 3.49 | | |

$\alpha = 0.05$

Table 4.5 shows a calculated t-test value of -6.838 and a P value of 0.000. Testing at an alpha level of 0.05, the P value is less than the alpha level. It shows that the null hypothesis which states that 'There is no significant difference in the level of understanding of chemical concepts by those exposed to instructions on chemical concepts and those who were not, is not accepted. Consequently, there is a significant difference in the level of chemical concepts understanding of those exposed to the instructions on chemical concepts and those who were not.

Since the mean score of the Experimental Group 27.93 is greater than the mean of Control Group which is 25.94, it shows, therefore that those exposed to chemical concepts instructions had better level of understanding of chemical concepts than those who were not.

### 4.2.2 Test of Hypothesis Two ($Ho_2$)

There is no statistically significant difference between students exposed to instructions in chemical concepts and those not exposed to chemical concepts instructions in their achievement in biochemical topics.

**Table 4.6: Description of students' post-test achievement in biochemical topics**

| Group | Mean | Std. Deviation | N |
|---|---|---|---|
| Control | 17.1246 | 3.28270 | 289 |
| Experimental | 20.2277 | 2.93488 | 303 |
| Total | 18.7128 | 3.47317 | 592 |

Table 4.6 shows a post-test mean of control group as 17.12 and post mean for the experimental group as 20.23. Therefore the experimental group performed better than the control group as it has been further proved by the lower standard deviation of 2.93488 for the experimental group than the 3.28270 for the control group.

**Table 4.7: ANCOVA Summary Table for Post-test for Achievements on Biochemical Topics**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 3996.685[a] | 2 | 1998.343 | 375.746 | .000 |
| Intercept | 323.054 | 1 | 323.054 | 60.743 | .000 |
| Pre Bio-Chem | 2572.306 | 1 | 2572.306 | 483.668 | .000 |
| Group | 883.887 | 1 | 883.887 | 166.196 | .000 |
| Error | 3132.497 | 589 | 5.318 | | |
| Total | 214430.000 | 592 | | | |
| Corrected Total | 7129.182 | 591 | | | |

a. R Squared = .561 (Adjusted R Squared = .559)

Table 4.7 shows an F value of 166.196 and a P value of 0.000. Testing at an alpha level of 0.05, the P value is less than the alpha level, so the null hypothesis which states that 'There is no significant difference between students who have understanding of chemical concepts and those who do not have in their achievement in biochemical topics of photosynthesis, respiration, diffusion and osmosis, carbohydrates, protein, fats and enzymes' is rejected. There is therefore a significant difference between students' chemical concept understanding level and their achievement in biochemical topics of photosynthesis, respiration, diffusion and osmosis, carbohydrate, protein, fats and oil, and enzymes. So there is a significant effect of students' chemical concepts understanding on their achievement in the biochemical topics investigated in this study.

**Table 4.8: Pair wise Comparison of Students Post-test achievements in Biochemical Topics**

| (I) Group | (J) Group | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| Control | Experimental | -2.472* | .192 | .000 | -2.849 | -2.096 |
| Experimental | Control | 2.472* | .192 | .000 | 2.096 | 2.849 |

*Based on estimated marginal means*

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

*a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).*

Table 4.8 shows a mean difference of experimental and control as 2.472 and a P value of 0.000. Since the P value is less than 0.05 ($P<0.05$), it shows therefore that students who have understanding of chemical concepts achieved more in biochemical topics than those who do not have chemical concepts understanding.

### 4.2.3 Test of Hypothesis Three ($Ho_3$)

There is no statistically significant treatment by gender interaction effect of students exposed to instruction in chemical concepts and those not exposed to instructions in chemical concepts in their achievement in biochemical topics.

**Table 4.9: ANCOVA Treatment by Gender Interaction on Post-test on Biochemical Achievement Test (BAT)**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 4010.467[a] | 4 | 1002.617 | 188.711 | .000 |
| Intercept | 328.210 | 1 | 328.210 | 61.775 | .000 |
| Pre Bio Chem | 2536.102 | 1 | 2536.102 | 477.341 | .000 |
| Group | 884.598 | 1 | 884.598 | 166.498 | .000 |
| Sex | 13.664 | 1 | 13.664 | 2.572 | .109 |
| Group * Sex | .025 | 1 | .025 | .005 | .946 |
| Error | 3118.716 | 587 | 5.313 | | |
| Total | 214430.000 | 592 | | | |
| Corrected Total | 7129.182 | 591 | | | |

a. R Squared = .563 (Adjusted R Squared = .560)

Table 4.12 shows an F value for the groups by gender interaction as 0.005 and a P value of 0.946. Testing at an alpha level of 0.05, the P value is greater than the alpha level. So the null hypothesis which states that 'There is no significant treatment by gender interaction effect on students achievement in biochemical topics, is retained. Consequently, the treatment is equally effective for male and female students.

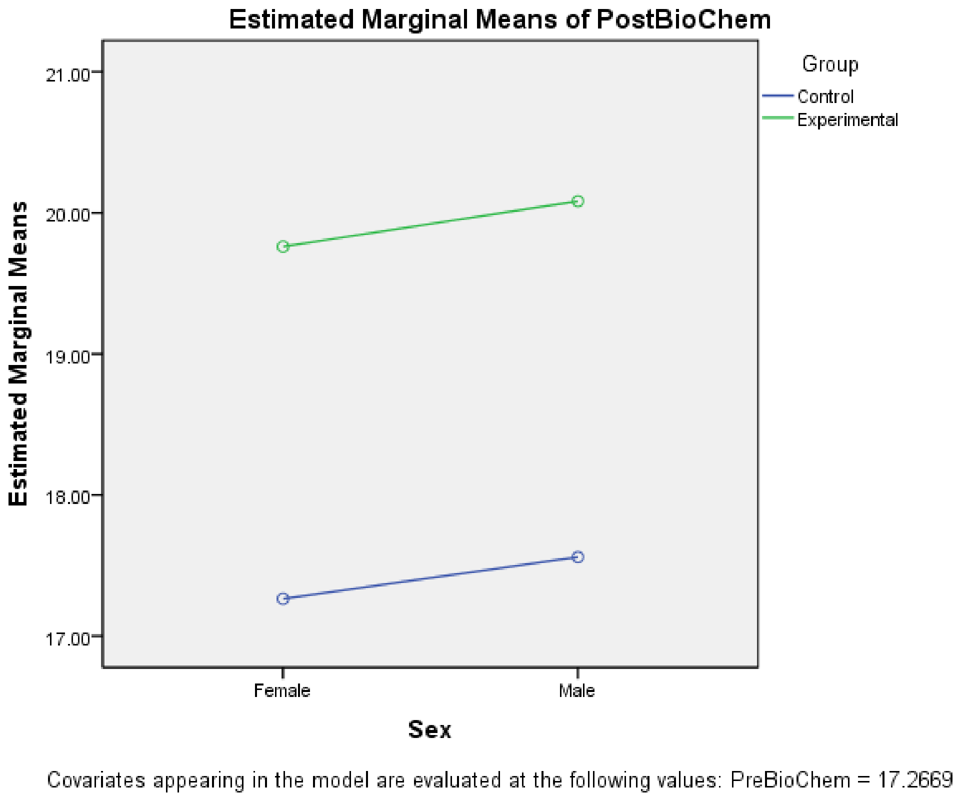


Fig. 4.1 – Gender Interaction on Biochemical Topics

Figure 4.1 shows that there is no interaction, since the two lines did not meet .Therefore like table 4.12 there is no gender interaction effect on the students' achievement in biochemical topics.

### 4.2.4 Test of Hypothesis Four ($Ho_4$)

There is no statistically significant location interaction effect of students exposed to instructions in chemical concepts and those not exposed to instruction in chemical concepts on their achievement in biochemical topics.

**Table 4.10: ANCOVA of Treatment by School location interaction on Post-test on Biochemical Achievement Test (BAT)**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 4037.377[a] | 4 | 1009.344 | 191.631 | .000 |
| Intercept | 310.015 | 1 | 310.015 | 58.858 | .000 |
| Pre Bio Chem | 2572.581 | 1 | 2572.581 | 488.422 | .000 |
| Group | 680.871 | 1 | 680.871 | 129.268 | .000 |
| Location | 23.431 | 1 | 23.431 | 4.449 | .035 |
| Group * Location | 10.095 | 1 | 10.095 | 1.917 | .167 |
| Null Error | 3091.806 | 587 | 5.267 | | |
| Total | 214430.000 | 592 | | | |
| Corrected Total | 7129.182 | 591 | | | |

a. R Squared = .566 (Adjusted R Squared = .563)

Table 4.14 shows an F value of the group by school location interaction as 1.917 and a P value of 0.167. Testing at an alpha level of 0.05, the P value is greater than the alpha level. So the null hypothesis which states that the 'There is no school location interaction effect on student achievement on biochemical topics' is retained. Consequently, the treatment is equally effective for urban and rural students.

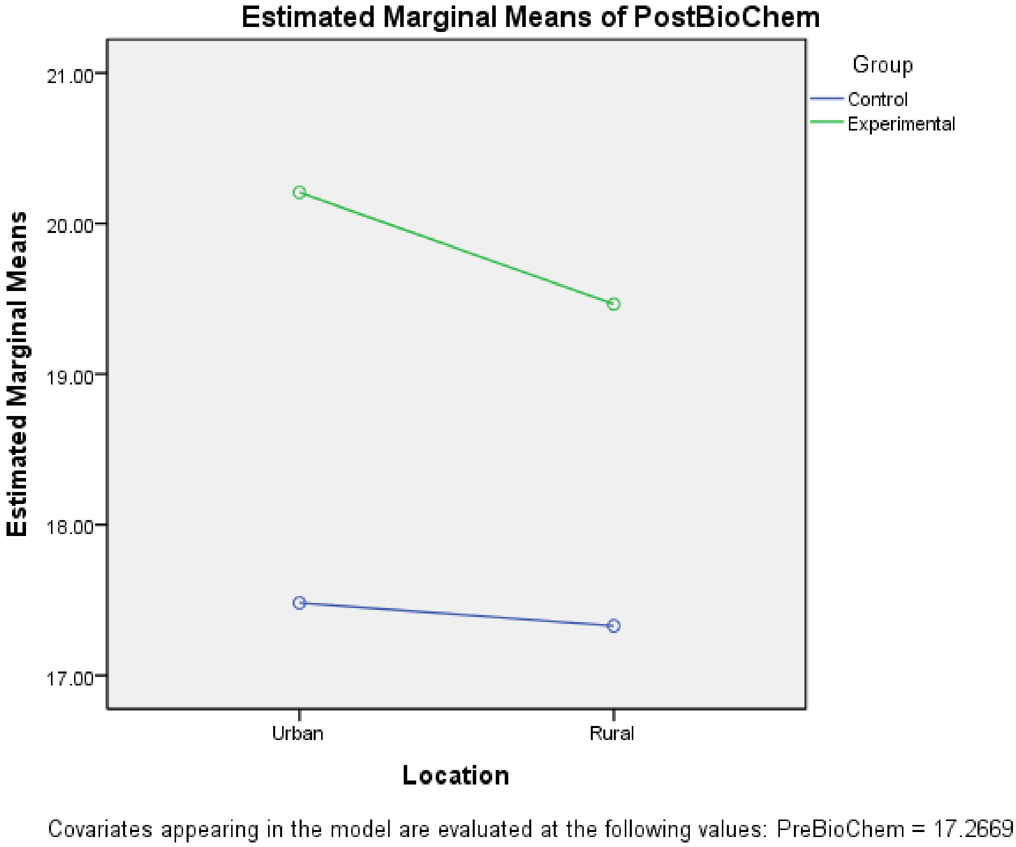


Fig. 4.2 – Location Interaction on Biochemical Topics

Figure 4.2 above shows that there is no interaction, since the two lines did not meet. Therefore like table 4.14, there is no school location interaction effect on the students' achievement in biochemical topics of photosynthesis, respiration, osmosis and diffusion, carbohydrate, protein, fats and oil, and enzymes. Therefore, the treatment was equally effective for Urban and Rural students.

**4.2.5 Effect Size of the Intervention on the samples**

Effect Size (Cohen`s d) (Cohen, 1988; Baguley, 2009) based on Table 4.6 values of the mean scores and standard deviations of the experimental and control sample groups was calculated to be 0.9966 approximated to 1.0. On a range of -3.0 to +3.0, a Cohen`s d of 1.0 in this study is considered to be of a large effect size in favour of the experimental group students who were specially taught relevant chemical concepts before teaching them the biochemical concepts.

## 4.3 QUALITATIVE DATA ANALYSIS for the Study

**Table 4.11: Data Analysis**

| S/N | Category | Sub-category | Responses | |
|---|---|---|---|---|
| | | | Good understanding | Fair understanding |
| 1 | Level of students understanding of chemical concepts | Physical change | 6(100%) | 0 |
| | | Chemical change | 3(50%) | 3(50%) |
| | | Elements | 3(50%) | 3(50%) |
| | | Compounds | 3(50%) | 3(50%) |
| | | Mixture | 6 (100%) | 0 |
| | | Valency | 3(50%) | 3(50%) |
| | | Chemical symbol | 3(50%) | 3(50%) |
| | | Chemical formula | 3(50%) | 3(50%) |
| | | Simple equation | 3(50%) | 3(50%) |
| | | Molecular structure | 3(50%) | 3(50%) |
| 2 | Effects of student understanding of chemical concepts on | Chemical concept | 5(83.3%) | 1(16.7%) |

| | | | | |
|---|---|---|---|---|
| | the understanding of biochemical topics | | | |
| 3 | Interaction between understanding of chemical concepts and achievement in biochemical topics | Chemical concepts | 6 (100%) | 0 |

Category 1 in Table 4.11 is about *Level of students understanding of chemical concepts:* The interviewees were asked: *What is the level of students understanding of chemical concepts of physical and chemical changes?* All the two teachers and four students that were interviewed clearly stated that students do not normally have challenges and problems with the understanding of physical change and mixtures as chemical concepts. They claimed that they all have high levels of understanding of these two concepts giving such reason that the two concepts are not as abstract as elements, valency, chemical formula, molecular formula and chemical equation. On the other hand, all the six respondents became divided in an interesting manner of 50/50 saying that elements, valency, chemical formula, molecular formula and chemical equation concepts are difficult to understand and students have an average low level of understanding of the concepts.

The second category, Effects of student understanding of chemical concepts on the understanding of biochemical topics shown in Table 4.11 proves that as much as 5 out of 6 (83.3%) of the respondents have some high level of understanding of biochemical topics or concepts.

### 4.4 Discussions

#### 4.4.1 Quantitative Research Results

The result of the study of quantitative research was discussed under the following sub-headings:

1. i. Level of chemical concepts of students and the

   ii. Effect of chemical concept instructions on students understanding level of chemical concepts.
2. Main effect of chemical concepts instruments on students' achievement in biochemical concepts
3. Interaction effect of gender
4. Interaction effect of location.

1. **(i)** ***Level of chemical concepts understanding of students*** **–** The result presented on table 4.4 shows that the P value (0.822) is greater than the alpha value (0.05). Therefore, there is no significant difference between the two groups, at pre-test stage. Also from the table percentage mean score of both groups were 46.5% and 45.60% for control and experimental groups respectively. Percentage mean score of less than 50% and 50% or more was considered as indicative of low and high level of chemical concept understanding respectively. The students' chemical concept understanding level is not high. This result is in line with the results of Khan (2011) who investigated the existing level of understanding of chemistry concepts among class IX. He found that the existing level of understanding of concepts in the subject of chemistry among class IX students was not high.

   **(ii).** ***Main effect of chemical concept instruction on students' chemical concept understanding levels*** **–** The results of the analysis carried to find out if there is any difference between the experimental and control group in their chemical concept understanding level shown on table 4.5. The P-value (0.00) is less than the alpha value of (0.05). It shows that there is a significant difference between the two groups. The experimental group performed better than the control group. Also the mean score of the experimental group (27.9) is greater than the mean score of the control group (25.94). The experimental group therefore had better level of chemical concept understanding level than the control groups.

2. ***Main effect of chemical concepts understanding level on biochemical topics*** – The results of the analysis carried out are shown on tables 4.6, 4.7 and 4.8. Table 4.6 shows the mean score of 20.23 and 17.12 respectively for the experimental and control groups respectively. The mean score of the experimental group is higher than the mean score of the control groups. The experimental group therefore had higher achievement in biochemical topics. Table 4.7 shows an F value of 166-196 and a P value of 0.000. The P value is less than the alpha (0.05) value. Therefore, there is a significant difference between the achievement of the experimental and control groups in their achievement in biochemical topics.

   Table 4.8 (Pair wise comparison of students' achievement in biochemical topics) shows a mean difference of experimental and control group as 2.472 and a P value of 0.000. P is less than the alpha value 0.05. The experimental group therefore achieved more than the control group in biochemical topics. This result is in line with the result of Beskeni, Yusuf, Awang, Ranjhal (2011), who reported that the knowledge of biochemistry concepts requires the knowledge of chemical concepts. They investigated how effective prior knowledge can help in the understanding of difficult chemistry concepts at secondary school level teaching and found out that prior knowledge has tremendous implication in the teaching and learning of chemistry. It is also in line with the work of Villafane, Loertscher, Minderhout, Lewis (2011) who in their work stated that learning depends on the application of priory learned concepts from general chemistry and biology to new biological context. They said also that for meaningful learning to take place there must be relevant concepts available within the cognitive structure which can be linked with the new material (Nwagbo, 2009).

3. ***Interaction effect on gender* –** Table 4.9 and fig. 1 are on gender interaction. Table 4.8 shows an F value for the groups by gender interaction as 0.005 and a P value of 0.946. The P value is greater than the alpha value (0.05). Therefore, there is no treatment by gender interaction effect on students' achievement in biochemical topic. So the treatment is equally effective for male and female students.

   The graph in Fig. 1 shows that there is no gender interaction effect on level of biochemical concepts, since the two lines did not meet. Therefore, there is no treatment by gender interaction effect on students' achievement in biochemical topics. The result is in line with the result of Olumide (2012) and Suleiman (2012) whose studies reported that gender has no significant effect on students' achievement in the concept of science. It also agreed with Geban, Ceylan (2010) and Muzue (2014) whose studies where on the use of some conceptual change teaching strategy, showed that there was no significant effect of interaction between teaching methods and gender on students' achievement. However, it does not agree with the work of Abdul-Raheem

(2012) and Stephen (2010), whose study revealed that there was significant effect of gender on students' achievement in scientific concepts (males had significant higher achievement scores than females.

4. ***Interaction effect on location*** – Table 4.10 and 4.2. Table 4.10 shows an F value of the group by school location interaction as 1.917 and a P value of 0.167. P value is greater than the alpha value. There is therefore no treatment by location interaction effect on students' achievement on biochemical topics. The treatment is equally effective for both urban and rural.

   Figure 4.2 graph shows that there is no interaction between location and level of understanding of biochemical topics since the two graphs did not meet. The treatment is equally effective for the two groups of urban and rural schools. This is in line with the work of Ezeudu and Obi (2013) in a study of the effect of gender and location on student achievement in chemistry in secondary schools in Nsukka Local Government Area of Enugu State.

### 4.4.2 Findings for Qualitative Research

The analysis of study showed that all the 4 (100%) students have high level of understanding of the concepts of physical change and mixtures but low level of understanding of the concepts of chemical change, compounds, elements, valency, chemical symbols, chemical formula, simple equations and molecular structure. 5 or (83.3%) of the respondents stated in the interview sessions that understanding of chemical concepts influenced their understanding and achievement of biochemical topics. All the 6 (100%) interviewees (two teachers and four students) responded and discussed in the same way that understanding of chemical concepts influence students' achievement in biochemical concepts.

- The researcher posed several questions to both the teacher and student interviewees. Among the questions asked to the teachers was: `*Do your students find it easy to understand chemical symbols and valency as topics?*`

One of the teacher-interviewees responded that:

- *"Students also find it difficult to understand chemical symbols and valency, and it requires patience from the teacher.*

*Would you think there is anything special to effectively teach chemical concepts? If yes, what could it be?*

- *Yes, there are issues about these chemical concepts.*

  - *In writing chemical symbols, students get confused, as the symbols are seen to be difficult to be understood because they represented in letters.*
  - *A child asked in the class why the symbol "Na" is used for sodium.*
  - *These chemical concepts (chemical symbols and valency) require more skills to teach in order for students to gain the required understanding."*

On the other hand, a student-interviewee said that:

**"***When you start to learn valency, chemical symbol, chemical formula, they are difficult at first, but as you get use to them and use them all the time, they become easier."*

After the special teaching process of this study based on emphasis on both ideas (concepts) and skills, problem-based interactive learning with emphasis on concept connections (Copley, 2008), the student interviewees were asked to answer the interview question that says *Do you consider that these chemical concepts as a key to your learning and understanding of Kreb's cycle in respiration and did you find any* *impact of them*? One of the student-interviewees said that*:*

> *"Now, we are in SS2 (Senior Secondary School Two), what we are doing in chemistry has helped us to understand Kreb's cycle, when you read Kreb's cycle and all these topics you are talking about, you will really know their formula and it is better for you to understand."*

# CHAPTER FIVE

## SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

This chapter is discussed under the following sub-headings.

1. Summary of the study.
2. Conclusion.
3. Implications
4. Contribution of the study to Knowledge.
5. Recommendation
6. Limitations of the study
7. Suggestion for further study.

### 5.1 Summary of the Study

The research studied the effects of chemical concept understanding level on students' achievement in biochemical topics. To guide the study, four (4) research questions and four null hypotheses at $p \leq 0.05$ were raised to guide the study. The research questions were as follows:

1. Is there a difference in students' chemical concept understanding level between students exposed and those not exposed to instructions on chemical concepts (physical and chemical change, elements, compounds, mixtures, valency, chemical symbol, chemical formula, simple equation, and atomic structure)?
2. Is there a difference in achievement level in biochemical topics (photosynthesis; respiration; diffusion and osmosis; carbohydrates, proteins, fats and enzymes) between students exposed to instruction in chemical concepts and those not exposed to instructions in chemical concepts?
3. Is there any gender interaction effect of students on their achievement in

biochemical topics?

4. Is there any location interaction effect of students exposed and those not exposed to instructions in chemical concepts on their achievement in biochemical topics?

The null hypotheses tested at $P \leq 0.05$ for the study were as follows:

1. There is no statistically significant difference in students` level of conceptual understanding between students exposed and those not exposed to instructions on chemical concepts.
2. There is no statistically significant difference in achievement level between students exposed and those not exposed to instructions in chemical concepts before being taught biochemical topics.
3. There is no statistically significant gender interaction effect on achievement in biochemical topics of students exposed and those not exposed to instruction in chemical concepts.
4. There is no statistically significant location interaction effect on their achievement in biochemical topics of students exposed and those not exposed to instructions in chemical concepts.

The design for the study was the non – randomized control group pre – test post – test quasi experimental design. The design reduces the possibility of manipulation and the results can be generalized. The population of the study consisted of all senior secondary two (2) students in the twenty five Local Government Areas of Delta State in Nigeria. Six secondary schools randomly selected from the three senatorial districts were used for the study. Three (3) of the schools were taken for experimental group and the other three (3) for control group. Intact classes were used for the two groups giving rise to a total sample of five hundred and ninety two (592) students. The study was done using mixed method approach of both quantitative and qualitative methods. The research instruments used were the Test of Students' Understanding of Chemical Concepts (TOSUCC) and Biology Achievement Test (BAT) which tested achievement in biochemical topics and Interview Schedule on two teachers and four students. The instruments were found to be valid and reliable on testing using the pilot study data.

The final data collected were analyzed using Analysis of Covariance (ANCOVA) for the hypotheses at 0.05 significant levels. Mean rating and t – test for the research question. The interview responses were qualitatively analyzed for deeper understanding and triangulation of the quantitative results.

## 5.2 Research Findings and Conclusion

The analyses of the results from data collected show the following findings.

1. There is a statistically significant difference in students understanding when exposed to instructions on chemical concepts without any special treatment. The level of student's chemical concept understanding for the experimental and control groups was low at the pre-test stage (at the beginning of the study). The result of the study shows that the chemical concept understanding of students is low. This may be why performance is poor in Senior Secondary School Examination (SSCE). The experimental group that had instructions on chemical concepts performed better than the control group that did not.
2. There is a statistically significant difference between students exposed to instructions in chemical concepts and those not exposed to chemical concepts instructions in their achievement in biochemical topics. The treatment approach was very effective in enhancing achievement of the participants in biochemical topics. This shows that chemical concept understanding aids the

understanding of biochemical topics. This is in agreement with Omoifo (2012). Therefore if students understand chemical concepts, they will have better achievement in biochemical topics.

3. There is no statistically significant difference resulting from treatment in terms of gender interaction effect of students exposed to instruction in chemical concepts and those not exposed to instructions in chemical concepts in their achievement in biochemical topics. The result shows that there is no significant treatment by gender (male and female) interaction effect on students' achievement in biochemical topics. The treatment is equally effective for male and female students.
4. Prior knowledge of chemical concepts is important for the teaching and learning of biochemical topics in biology and that chemical concept understanding is a pre – requisite for the understanding of biochemical topics. This implies that learning biochemical topics depends on the application of previously learnt chemical concepts.
5. There is no statistically significant difference resulting from treatment in terms of location interaction effect of students exposed to instructions in chemical concepts and those not exposed to instruction in chemical concepts in their achievement in biochemical topics. The result shows that there is no significant treatment by location (urban and rural) interaction effect on students' achievement in biochemical topics. The treatment is equally effective for male and female students.

The findings of this study tend to agree with the result of Beskeni, Yusuf, Awang, Ranjhal (2011), who said that the knowledge of biochemistry concepts requires the knowledge of chemical concepts. They investigated how effective prior knowledge can help in the understanding of difficult chemistry concepts at secondary school level teaching and found out that prior knowledge has tremendous implication in the teaching and learning of chemistry. The findings here also are in line with the work of Villafane, Loertscher, Minderhout, Lewis (2011) who in their work stated that learning depends on the application of priorly learned concepts from general chemistry and biology to new biological context. They said also that for meaningful learning to take place there must be relevant concepts available within the cognitive structure which can be linked with the new material. Khan (2011) in his article said that existing level of understanding of concepts to the subject of chemistry among class IX students was not high.

## 5.3 Implications of the Study

1. Biology students in some schools in Delta State have low level of chemical concepts understanding. Students who had higher chemical concepts understanding level achieved better than those without in biochemical topics. The low level of chemical concept understanding of chemical topics by students has implication in their learning of the biochemical topics. There is the probability that secondary school biology and chemistry teachers do not find out students' prior knowledge or the fundamental concepts that are needed for the understanding of the biochemical topics. The findings of this study would therefore enhance better teaching and learning through conceptual teaching for conceptual meaning and understanding.
2. The treatment strategy reviewed in this study will provide educational psychologists, guidance counselors, teachers and principals of secondary schools with guidelines for future educational diagnosis aimed at improving educational system in Nigeria.

3. The study will enhance policy making of the federal government and non-governmental organizations on educational issues regarding *what is to be taught, why it should be taught and how it should be taught* in Nigeria.
4. The study would serve as an eye opener to researchers on the educational system, as it will open doors for various similar researches on the issue.

### 5.4 Contributions of the Study to the Body of Knowledge

- One major achievement of this study is that it has been able to demonstrate that learners' understanding of chemical concepts and achievement in biochemical topics can be improved upon.
- The study revealed that there is significant difference between students' chemical concept understanding level and their achievement in biochemical topics of photosynthesis, respiration, diffusion and osmosis, carbohydrate, protein, fats and oil, and enzymes. The study with an effect size of Cohen`s d equal to 0.9996 (approximately 1.0) shows that better achievement in biochemical topics require the understanding of relevant chemical concepts. It proved beyond the usual p-value expression and is considered large enough to make for improved achievement in biochemical topics based on the treatment given to the experimental group sample. This makes the study peculiar, thus contributing to knowledge.
- This study will enable students to be able to look at issues objectively because they can comprehend and apply the knowledge that they acquired through concept understanding instruction.
- The result from this study provides a quality information and data that would be an asset for curriculum planners and biology teachers for planning instruction.

- The teachers in particular should use the outcome of this study to improve on their teaching, emphasizing on concept understanding in their teaching and prior learning/knowledge or pre – requisite concepts as was once suggested by Wright, Cotner and Winkel (2009). This is because certain chemical concepts are required before the teaching of the main topics (Biochemical topics in this case).
- The result of this study has a lot of implications to school authorities in the allocation of teachers to classes due to the problem of shortage of biology and integrated science teachers in schools. The general norm is that the more experienced ones are sent to the final year classes (Junior Secondary three (3) and senior secondary three (3)), leaving the junior classes to unqualified and inexperienced teachers. Therefore the foundation becomes faulty as a result of this practice. Some of the teachers too, avoid teaching some topics because they do not have good understanding of these chemical and biochemical topics.

### 5.5 Recommendations

The following recommendations and suggestions have been advanced based on the outcome of this study:

1. That before teaching biochemical topics, teachers should test students' level of knowledge of relevant and related chemical concepts.
2. To the curriculum planners, the topics that involve biochemical concepts should be preceded by chemical concepts as this will ensure higher learning achievement in biochemical topics from students.
3. Biology teachers without good background of chemistry should be encouraged to go for refresher courses in chemistry to enhance the teaching and learning

of biology.

4. Secondary school biology and chemistry teachers should teach for concept understanding, topics that are related to the new topics before teaching the topics.

## 5.6 Limitations of the study

The study, in its unique contribution to knowledge has shown that students' chemical concept understanding level could significantly affect their achievement in biochemical topics. Yet, the study encountered a lot of limitations in the course of the study. A limited number of 592 students were used due to administrative, logistics and time constraints. The study was also limited as it was only carried out in Delta State, Nigeria.

## 5.7 Suggestions for further studies

It was not possible for researchers to dive into every aspect of students' achievement in Biology within the time frame. The following suggestions are made for future work.

A further replication of this study could be established to widen the scope of this research as this study was limited to secondary school students in Delta State. The study should be carried in other states in Nigeria so as to broaden the generalizations of this study.

Other biochemical topics in the biology secondary school curriculum that were not used for this study could be used for other studies. Survey studies could be carried out so as to further widen researchers' perspectives about these phenomena.

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APPENDICES

## APPENDIX I

### LESSON PLAN ON CHEMICAL CONCEPTS

**WEEK 1**

Subject - Integrated Science

Class - SS 2

Duration: 3 Periods of 40 minutes each.

Topic – Matter

Description of new content: Definition of matter, Classification of matter, States of matter.

Instructional objectives:

By the end of the lessons the students should be able to:

(i) Recognize that all living and non- living things are made up of matter

(ii) Recognize that all things in our surroundings are forms of matter.

(iii) List the three states of matter.

Instructional Materials

Live specimens – rats, cockroaches, charts, plastic containers, polythene bags, soil etc.

Period 1

Sub-topic: Definition and Identification of matter

Introduction – 5 minutes

Students are asked to

(1) Mention some of the things in their surrounding

(2) Classify them into soft and hard, long and short, living and non-living things etc.

Presentation – 15 minutes

Step 1

Teacher and students walk round the school compound to collect samples of matter (living and non – living matter).

Step 2

Students are asked to classify the materials into soft and hard, long and short, living and non-living things.

Step 3

Students are asked the following questions:

(i) Do the materials occupy space?

(ii) Do they have mass?

Step 4

Students are led to define matter and give more examples of matter while the teacher writes them on the chalkboard.

Conclusion – 10 minutes

Teacher evaluates the lesson by asking the following questions

(1) Define matter.

(2) Classify stone, rat, rose flower, car, plastic containers, chalk, etc. into living and non-living matter.

(3) What are all living and non-living things made up of?

(4) Classify matter into solid, hard, soft.

Assignment

(1) Define matter

(2) List 20 things in your environment and classify them into living and non – living.

(3) Read about change of state.

Period 2

Sub-topic: States of matter.

Introduction 5 minutes

Revision of the last lesson:

What is matter?

Matter was classified into solid, liquid, gas

Presentation – 15 minutes

Step 1

Students are divided into groups for class discussion. Students observe and classify matter further into solid, liquid, long, short, black etc.

Step 2

Teacher talks about air in the classroom – it is a matter and made up of matter also. Breathe in and out. How do you feel the size of your chest region? Explain a state of matter with ice block.

Step 3

Students are led to understand that matter is classified into three groups – solid, liquid, and gas.

Conclusion

Teacher goes over the lesson briefly again to summarize the lesson.

Evaluation questions:

1. What are living and non – living things made up of?
2. Into many states does matter exist?
3. State the three states of matter.

Assignment

Read more about the states of matter and what matter is made up of.

Period 3

Sub-topic: State of matter and what matter is made up of.

Introduction: The last topic is revised with the students.

Presentation: Students are led to describe solid, liquid and gases.

Step 1 – Teacher explains that the way particles are arranged determines their state and that when heat is applied to matter, it can change from one state to the other.

Activity: Ice block is left to melt in a container, put back into the freezer for it to turn back to block again.

Conclusion

Teacher briefly goes through the lesson again.

Evaluation questions:

Define matter.

State the three states of matter.

What are living and non-living things made up of?

Assignment

Students are asked to collect related materials for the next lesson.

**WEEK 2**

Class – SS 2

Subject- Integrated Science

Topic: Changes in non-living things.

Sub-topics: Physical and Chemical changes.

Duration: 40 minutes.

Description of content

Types of physical changes and chemical changes, characteristics of physical changes

Prerequisite knowledge/Assumed knowledge or entry behavior – students have done state of matter

Instructional objectives:

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

(1) Observe and describe changes in non-living matter.

(2) Group such changes as physical and chemical changes.

(3) State the physical and chemical changes.

Instructional Materials – candle sticks, ice blocks, fire wood, matches, burnsen burner, tripod stand, cubes of sugar, beakers.

Period 1 and 2

Topic: Physical and Chemical changes.

Introduction – Revision of last lesson.

Presentation – Teacher demonstrates the processes of physical and chemical change with the instructional materials.

Step 1

Teachers and students perform activities that lead to changes in non-living things as follows:

- Heating of candle wax
- Melting of ice block
- Mixing of sugar and water

**Chemical changes:**

Burning of the candle wax

- Burning of a piece of wood
- Burning of a piece of paper
- Striking of match stick

Step 2: Students' record their observations.

Step 3: Class discussion – students' are divided into groups.

Step 4: Discus briefly. Teacher leads class discussion on change in non-living matter.

Step 5: The changes are not put on the blackboard as students mention them.

Conclusion: Teacher summarizes the lesson briefly.

Evaluation: students answers these questions

1. Define physical changes.
2. List three examples of chemical and physical change.
3. List three differences between chemical and physical change.
4. Identify physical and chemical changes.
5. State two changes which occur in non-living things.

**WEEK 3**

Class: SS2

Subject: Integrated Science

Duration – two periods of 40 minutes

Topics – Non-living things – Elements, compounds and mixtures

Description of new content: Element, compound and mixture – examples, properties, symbols and formulae.

Prior knowledge / entry behavior /assumed knowledge – students' have been taught chemical and physical change.

Instructional objectives:

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

1. Describe elements, compound and mixture with examples.
2. Describe their properties and uses.

<u>Instructional materials</u>

Empty tins, iron, table salt, palm oil, kerosene, clay, water, sand, charts, gold, zinc, aluminum, lead charts etc.

<u>Period 1</u>

Introduction: Teacher revises physical and chemical change with students.

Presentation

<u>Step 1:</u>

Teacher ask the following questions

- ➢ What is an element?
- ➢ What is a compound?
- ➢ What is a mixture?

<u>Step 2:</u>

Teacher and students define elements, compounds and mixtures.

<u>Step 3:</u>

Teacher guides students to the identify compounds, mixtures and elements from the instructional materials.

Period 2

Teacher introduces the word *symbol* by asking the student what *symbol* means. Teacher shows the symbols of different elements by pointing at the pictures on the charts.

Step 5:

Teacher illustrates how the symbols are derived from their Latin names and capital form of the first letter together with another letter in the name.

Step 6:

Teacher briefly summarizes the lesson, and asks the students to copy from the already prepared note in the chart.

Mixture: This is a combination of elements that are physically combined e.g. stones and water, petrol and water.

Compound: It is a combination of elements that are chemically combined together e.g. sodium chloride.

Element: An element is a substance that cannot be broken down into any other substance by any known chemical reaction or process.

**Chemical Symbols:**

(a) Names got from the first (capital letter)

| Elements | Symbols |
|---|---|
| Hydrogen | H |
| Nitrogen | N |
| Oxygen | O |
| Carbon | C |
| Boron | B |
| Iodine | I |

(b) Names got from the first letter plus a letter in the name

| Elements | Symbols |
|---|---|
| Argon | Ar |
| Bromine | Br |
| Beryllium | Be |

(c) Symbols derived from Latin names.

| Elements | Latin name | Symbols |
|---|---|---|
| Sodium | Natrium | Na |
| Potassium | Kalium | K |
| Mercury | Hychargyrium | Hg |
| Iron | Ferrum | Fe |
| Gold | Aurium | Au |
| Silver | Argentums | Ag |

Evaluation questions:

1. Write out the chemical symbol of hydrogen, oxygen and nitrogen.

2. List three elements whose names are derived from their Latin names.

3. Write out the chemical symbols for argon, beryllium and bromine.

## WEEK 4

Duration: Three periods of 40 minutes each.

Class: SS 2

Subject: Integrated Science

Topic: Formula and chemical equation

Prerequisite Knowledge/entry behavior:

Students have been taught elements, compounds, mixtures and symbols.

Instructional Objectives:

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

1. State the combining powers (valence of elements).
2. Write the symbols of the first twenty elements.
3. Write the formula of common compounds.
4. Write simple chemical equations.
5. Balance simple chemical equations.

Description of new content

1. Elements- symbols and formulae
2. Uses of common elements, compounds and mixtures e.g. gold, crude oil, kaolin

Instructional materials

Empty tins, table salt, palm oil, kerosene, clay, water, sand, charts, gold, zinc, aluminum, lead

Period 1

Sub-topics: combining power (valence) of elements, and chemical formulae of common compounds.

Introduction

Teacher revises the last lesson with the students.

Presentation

Step 1

Teacher shows the chart of the first twenty elements of the Periodic Table and their electrons in the K, L, M shells and introduce the concept of valency.

Step 2

Teacher guides students to explain what ion, cations, anions, electropositive, and electronegative ions are.

Step 3

Teacher explains electrovalent and covalent combinations.

Step 4

Teacher explains atomicity.

Conclusion

Teacher summarizes the lesson briefly.

Evaluation questions:

1. Put the electrons of sodium atom in the K, L, M shells.
2. Define ion, cation, and anion.
3. Explain what electronegative and electropositive ions are.
4. What is atomicity?
5. Define valency.

Assignment

1. Interpret the formulae represented in the following compounds: $H_2O$ (water), $NH_4Cl$ (ammonium chloride), $CH_4$ (methane), MgO (magnesium oxide).
2. Write the formula of sodium chloride ($Na^+Cl^-$), magnesium (II) tetraoxosulphate (VI) ($Mg^{2+}$ $SO_4{}^{2-}$), and magnesium chloride ($Mg^{2+}$ $Cl_2{}^-$)

Period 2

Sub-topic: Simple chemical equations

Introduction

Revision of the last lesson

Presentation

Step1

Teacher writes out the formula of some common compounds on the board.

Step 2

Teacher writes some chemical equations resulting from reactions with the compounds.

Step 3

Teacher explains about reactants and products of the reaction and gives the students information on reaction.

Step 4

Teacher gives many examples and asks students to practice some on their own.

Step 5

Students discuss and compare their equations.

Conclusion

Teacher summarizes the lesson briefly.

Evaluation

Write out the equations for reactions between:

1. Hydrogen gas and oxygen gas.
2. Sodium and chlorine molecules.
3. Sodium and water molecules.
4. Iron and oxygen molecules.

Assignment

Students are asked to practice more and learn how to balance equations at home.

Period 3

Sub-topic: Balancing of chemical equations

Introduction

Teacher revises the last lesson

Presentation

Step 1

Teacher writes some equations on the board with the students participating by stating what to write.

Step 2

Students are asked to write some equations on the chalkboard.

Step 3

Teacher explains the steps in balancing of equations to the students.

Step 4

Students are given many exercises to practice in class.

Conclusion

Teacher summarizes the lesson

Evaluation

Balance the following equations:

1. $Fe + O_2 \longrightarrow Fe_3O_4$
2. $Ca(OH)_2 + NH_4Cl \longrightarrow CaCl_2 + H_2O + NH_3$
3. $Cu + H_2SO_4 \longrightarrow CuSO_4 + H_2O + SO_2$
4. $Na + Cl \longrightarrow NaCl$
5. $Cl_2 + NaBr \longrightarrow Br_2 + NaCl$

6. $Na + H_2O \longrightarrow NaOH + H_2$

**APPENDIX II**

**Lesson Plans on Biochemical Topics**

**WEEK 1**

Period1

Class-SS 2

Subject - Biology

Duration - 40 minutes

Topic - Diffusion (Cell and its environment).

Description of content

Diffusion - definition, process and significance.

Prerequisite/Prior Knowledge

Students should have some basic knowledge of:

(1) Nature of matter (made up of tiny particles – atoms, molecules, ions)

(2) States of matter (solids, liquids and gases).

Instructional objectives:

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

(1) Define diffusion.

(2) Explain the process of diffusion.

(3) Demonstrate diffusion.

Instructional Materials

They include perfume, crystals of potassium permanganate, beaker, water, and bromine.

Introduction

Teacher introduces diffusion by asking the following questions.

(1) What is matter?

(2) What is matter made up of?

(3) List the three states of matters.

Presentation

Step 1

Teacher provides cheap perfume and request students to spray it at one end of the classroom.

Step 2

Students observe record and discuss their observations.

Step 3

Teacher guides students to define diffusion and then explain the process of diffusion and concentration gradient.

Step 4

Teacher places a crystal of potassium permanganate in a beaker of water and leave it to stand and ask the students to observe and record their observations.

Step 5

Students repeat the experiment, observe, record and discuss their observation. The experiment can be repeated with bromine.

Step 6

Teacher and students discuss the significance of diffusion and emphasize the importance of diffusion to the living system; and write them on the black board.

Conclusion

Teacher summarizes the lesson briefly.

Evaluation: The following questions are asked

(1) Define diffusion.

(2) Did you smell the perfume from the back of the classroom? Why?

(3) Explain the process of diffusion.

(4) What are the uses of diffusion?

(5) Give examples of diffusion in living things.

Assignment

Students are asked to read

(1) More about diffusion and perform more experiments at home;

(2) Osmosis before the next lesson.

**Chalkboard Summary**

Diffusion

Diffusion is the movement of gaseous or liquid molecules from a region of higher concentration to a region of lower concentration, through the medium of air or liquid.

Factors that speed the rate of diffusion

1. Heating or increase in temperature
2. Shaking or stirring.

Examples of Diffusion in Living Organisms

1. Diffusion of soluble digested food from the intestine to the with
2. Diffusion of food and oxygen from the blood to the cell and diffusion of carbon dioxide from the cells to the blood.
3. Diffusion of nutrients and gases from the mother's placenta to the foetus and waste products from the foetus to the placenta.
4. Diffusion of gases from the atmosphere into air cavities of leaves

Importance of diffusion

1. It ensures the movement of air in the intercellular spaces of flowering plants.
2. Through the process, mineral salts in solution in the soil enter the roots of plants.
3. Carbon dioxide and oxygen enter and leave the body of flowering plants.
4. It ensures exchange of gases (oxygen and carbon dioxide) during respiration.
5. Removal of waste products in small organisms e.g. amoeba is through diffusion
6. Digested food enters saprophytic plants e.g. mucor by diffusion.

Period 2

Class- SS2

Duration - 40 minutes

Subject- Biology

Topic- Cell in its environment

Description of new content

Osmosis - definition, process and significance, diffusion of water through a selectively permeable membrane.

Prerequisite/Prior Knowledge

Students have some basic knowledge of nature of matter, state of matter and diffusion.

Instructional objectives

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

(1) Define osmosis

(2) Explain the process of osmosis

(3) Recognize that that osmosis is a form of diffusion

(4) Demonstrate the process of osmosis.

(5) State the differences between diffusion and osmosis.

(6) State the importance of osmosis to plants and animals.

Instructional Materials

Pig's blade, thistle, funnel, sugar, peeled yam, stopper, clamp, onion cells, and water

Introduction:

Teacher revises the last lesson.

Presentation

Step 1

Teacher asks the following question

1. What is osmosis?

2. What is the difference between osmosis and diffusion?

Step 2

Teacher demonstrates experiments on osmosis in a

(1) Non – living system.

(2) Living system.

Step 3

Students observe, record and discuss their observations

Step 4

Teacher guides the students to define osmosis, explain the process, recognize that osmosis is a type of diffusion, state the difference between diffusion and osmosis, and the importance of osmosis to plants and animals.

Step 5

Conclusion

Teacher summarizes the lesson briefly.

Evaluation

Teacher ask the following questions

1. What is osmosis?
2. What is the function of semi–permeable membrane in the experiment on osmosis?
3. What are the uses of osmosis to plants?
4. What is the importance of osmosis to animals?

Assignment

Students are asked to read up plasmolysis, haemolysis and biological significance of the processes.

**Chalkboard summary**

Osmosis

Osmosis can be defined as

(1) The diffusion of water molecules across a semi–permeable membrane.

(2) The movement of water molecules through a selectively permeable membrane.

(3) The movement of water molecules from a region of lower concentration (low osmotic pressure) to a region of higher concentration (higher osmotic pressure) through a semi–permeable membrane.

(4) Semi–permeable membrane selects what goes in and out of the cell.

Osmotic pressure

Osmotic pressure is the pressure developed by a more concentrated solution e.g. sugar or salt solution when water moves into a semi permeable membrane.

Hypotonic is the solution which loses water in osmosis. (Low concentrated solution)

Hypertonic: This is the solution which gains water in osmosis (highly concentrated solution).

Isotonic: Here a state of equilibrium is established, between two solutions that is, neither solution gains or losses water.

Osmotic pressure: When two solutions A and B are in osmotic equilibrium, the rate of movement of water from A and B, equals the rate of movement from B to A.

Differences between diffusion of osmosis

| **S/NO** | **DIFFUSION** | **OSMOSIS** |
|---|---|---|
| 1 | Involves movement of molecules of gases, liquids, solids. | Involves only movement of molecules of water. |
| 2 | Semi–permeable membrane is involved. | Semi–permeable membrane is involved. |
| 3 | Molecules diffuse into any space that is accessible to them. | Water molecules more between to solutions of different osmotic pressure. |
| 4 | Occurs in both living and non-living things. | Occurs only in living things. |

Importance of osmosis to plants and animals

Plants

1. Absorption of water from the soil into the root heir is by osmosis.
2. Movement of water molecules from the root heirs to the cells of the cortex is by osmosis.
3. Osmosis helps in opening and closing of the stomata.
4. It gives turgidity to the plant cell. (That is, does not make it flabby or flaccid).

Animals

(1) Intracellular movement of water is by osmosis.

(2) The re-absorption of water in the kidney (kidney tubules) is by osmosis.

(3) Absorption of water from undigested food materials in the large intestine is by osmosis.

(4) It makes animal cells turgid.

(5) Haemolysis of the red blood cell is due to osmosis.

Period 3

Class – SS 2

Subject: Biology

Duration – 40 minutes

Topic – The cell and its environment.

Description of content: Haemolysis, plasmolysis, and osmometer.

Prerequisite/prior knowledge: Students have knowledge of what diffusion, osmosis, hypotonic, hypertonic, isotonic equilibrium are.

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

(1) Define plasmolysis, haemolysis and be able to explain what they are.

(2) Recognize that plasmolysis can lead to wilting

(3) Recognize that haemolysis can lead to loss of blood.

Instructional materials: Test tubes, distilled water, sodium chloride solution (same concentration as blood, 0.85%) sodium chloride 3.0%, few drops of mammalian blood, filament of spirogyra, slide, and microscope.

Introduction

Teacher Revises of the previous lesson on diffusion and osmosis.

Presentation

Step 1

Teacher demonstrates experiment on plasmolysis and students observe record and discuss their observation.

Step 2

Teacher demonstrates the effects of solutions of different strengths on red blood cells for experiment on haemolysis; students observe record and discuss their observations.

Step 3

Teacher guides students to define plasmolysis, and haemolysis. The meaning of turgidity and crenation are explained.

Step 4

Teacher explains what active transport is and together with students, talk about the significance of the process.

Conclusion

Teacher summarizes the lesson.

Evaluation questions:

The following questions are asked.

(1) Define plasmolysis.

(2) What is haemolysis?

(3) Why should haemolysis be prevented?

(4) Explain why red blood cells swell and later burst when placed in distilled water.

(5) What is the difference between turgidity and plasmolysis?

Assignment

1. State the differences between diffusion and osmosis.

2. State one difference between plasmolysis and turgidity.

3. What is haemolysis?

Read up cellular respiration before the next lesson.

**Chalkboard Summary**

Plasmolysis is the shrinkage of the vacuole and pulling away of the cytoplasmic linings from the cell wall when plant cell is placed in a concentrated salt solution.

If the plasmolysed cell is placed in distilled water or pure water, water moves into the cell sap by osmosis (endosmosis) because the cell sap in the vacuole is more concentrated. The vacuole increases in volume, and it is distended towards the cell wall. If the cell wall is distended until it cannot be further distended, the cell is said to be turgid and the condition is called turgidity. Plasmolysis can lead to death if it is allowed to continue for a long time.

Haemolysis is the bursting of the red blood cells in the plasma. Blood plasma and red blood cells are isotonic. If for some reasons the concentration of salt in the plasma falls (hypotonic), water will enter the red blood by osmosis (also called endosmosis) through the cell membrane. If water continues to enter and it is not controlled the cell will be turgid and will burst. This can lead to death (no cellulose in animal cells, to help to resist or withstand the turgidity)

If the concentration of the salt in the plasma is higher (hypertonic) water leaves the red blood cell by osmosis (also called exosmosis). The red blood cell will shrink (become plasmolysed). The shrinking of the cell is called crenation.

An example of this is seen when Epson salt, magnesium tetraoxosulphate (VI)

(Laxative) is taken. Water is drawn from the blood cell and other body fluids and the person will lose a lot of water through passing of watery stool. Frequent use of laxative can lead to crenation.

**Week 2**

Period 1

Subject: Biology

Class: SS2

Duration: 40 minutes

Topic: Properties and functions of cells.

Description of content: Cellular respiration – types aerobic and anaerobic (catabolism).

Prerequisite /Prior knowledge: students have the knowledge of cell structure diffusion, osmosis, symbols, chemical formula and chemical equation.

Instructional objective:

By the end of the lesson the students should be able to:

1. Show experimentally, that the breakdown of carbohydrate may be partial (fermentation) or complete.
2. Demonstrate the process of cellular respiration.
3. Define cellular respiration.
4. State the process of respiration.
5. Write the equation for respiration.
6. List the types of respiration.
7. List the products of respiration.
8. List the reactants for respiration.

Instructional materials

Life rat, glass jar, test tubes, two-holed rubber stopper, lime water, copper (II) tetraoxosulphate (VI) crystals, and bent glass tubing.

Introduction

Teacher revises the last lesson.

Presentation

Step 1

Teacher asks the following questions:

1. How do living things get energy?
2. How do you get the energy required for you to carry out life activities?
3. Do many organisms require oxygen and food to stay alive?
4. What is the source of energy in the cell?

Step 2

Students answer the questions with the teacher guiding them.

Step 3

Teacher demonstrates the experiment on respiration, using a life rat

Step 4

Teacher guides students through the process of identifying the reactants, products and other essential elements in the demonstration. Students share observation and make inferences on the process and the specific need for oxygen to burn food.

Step 5

Teacher explains and defines cellular respiration, types of respiration and uses of respiration (ATP-energy) to the students. Emphasize the sites for cellular respiration in the cell (mitochondria)

Conclusion

Teacher briefly summarizes the lesson.

Evaluation questions:

1. Define cellular respiration.
2. List the reactants for respiration.
3. List the product of respiration.
4. What is the site for cellular respiration in cell?
5. Write the equation for aerobic reaction.

Cellular respiration is different from breathing. Cellular respiration is a biochemical process that involves series of enzymatic reactions and electron transfer system in cells. In higher plants and animals, cellular respiration occurs in the mitochondria of the cells.

All living organisms require or need energy and for this, the glucose in the cells must be broken down. During cellular respiration glucose is broken down into carbon dioxide ($CO_2$) and water ($H_2O$) and energy is released. The energy is stored in ATP (Adenosine Triphosphate). The equation of cellular respiration is as follows:

$6C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_20$ + Energy (ATP) + Heat The reaction above shows aerobic respiration, food is completely broken down (oxidized), carbon dioxide and water are formed. Mitochondria are the sites for respiration in the cell. Mitochondria are spherical or rod-shaped organelles found within the cytoplasm of eukaryotic cells (higher plants and organisms). The mitochondria are usually referred to as the power house of the cell because they act as the site for the production of high-energy compounds like ATP, which are important energy source for several cellular processes.

Cellular respiration provide large amount of energy through oxidative phosphorylation of organic molecules during cellular respiration. In cellular respiration glucose and oxygen react to provide energy and water and carbon dioxide are released in the process for use in many metabolic processes.

Aerobic respiration takes place in three stages; which

1. Glycolysis
2. Kreb's cycle
3. Electron transport chain.

**Glycolysis**: It is the first phase of oxidation (breaking down) of glucose. It involves a series of step that are catalyzed by different enzymes. Glycolysis:

- Occurs in the cytoplasm
- Does not consume oxygen
- It is a common pathway for both aerobic and anaerobic respiration.
- It produces 2 molecules of pyruvic acid, 2ATPs as net product and $2NADH_2$

**Aerobic Respiration**

Aerobic respiration occurs in the mitochondria. It includes the Kreb's cycle and the electron transport chain and pyruvic acid formed from glycolysis diffuses into mitochondria and reacts with Coenzyme A to form acetyl-CoA (2 Carbon compound) in the inter membrane space of the mitochondria. As a result, $CO_2$ and $2NADH_2$ are produced from pyruvate in the inter membrane space of the mitochondria.

Period 2

Class: SS2

Subject: Biology

Duration: 40 minutes

Topic: Cell and its environment

Description of content: Anaerobic respiration, alcoholic fermentation.

Prerequisite /Prior knowledge:

Students have knowledge of chemical symbols, equation, formula and aerobic respiration.

Instructional objectives:

By the end of the lesson the student should be able to:

1. Define aerobic respiration?
2. Demonstrate the experiment for anaerobic respiration.
3. State the differences between aerobic and anaerobic respiration.
4. List the reactant and products of anaerobic respiration.
5. Write the equation for anaerobic respiration, alcoholic fermentation.
6. State what alcoholic fermentation is.

Instructional materials

Conical flasks, stoppers, rubber tubing, test tubes, lime water, glucose-yeast suspension, paraffin, life rat, and glass jar.

Introduction

Teacher revises the previous lesson.

Presentation

Step 1

1. How many types of respiration do you know?
2. Which organisms respire by the type of respirations you have stated?

Step 2

Teacher guides the students to answer the questions.

Step 3

Teacher demonstrates experiment on anaerobic respiration.

Step 4

Students observe record and discuss the experiments.

Step 5

Teacher guide the students to:

1. Define anaerobic respiration.
2. Write the equation for anaerobic respiration.
3. Compare aerobic and anaerobic respiration.
4. State the importance of alcoholic fermentation to breweries.
5. Explain the fact that the energy (ATP) produced in anaerobic respiration is much less than the one produced in aerobic respiration.

Conclusion

Teacher summarizes the lesson briefly.

Evaluation questions:

Teacher evaluate with these questions.

1. Define aerobic respiration?
2. What is the site for respiration?
3. State the differences between aerobic and anaerobic respiration?
4. List the reactants and products of anaerobic respiration.
5. Write the equation for anaerobic respiration.
6. Write the equation for alcoholic fermentation.
7. State importance or uses of ATP (energy).

Assignment

1. How many ATP molecules are formed from one molecule of glucose at the end of an aerobic respiration?
2. What is the role of oxygen in aerobic oxidation of food? Read Kreb's cycle

before next lesson.

**Chalkboard Summary**

Anaerobic respiration (alcoholic fermentation), this is the type of respiration in which the glucose is broken down the cells **without oxygen**. Alcoholic, carbon dioxide and 2ATP are produced.

$C_6H_{12}O_6 \longrightarrow C_2H_5OH + 2H_20 + 2CO_2 + 2ATP$ (Energy)

Glucose Ethanol

Most microorganisms respire anaerobically. Anaerobic respiration of yeast is called alcoholic respiration. In anaerobic respiration sugar is incompletely broken down.

Lactic acid fermentation: In another kind of anaerobic respiration, lactic acid and energy are produced in a series of enzymatic reactions (glycolysis).

$C_6H_{12}O_62CH_3CH(OH) \longrightarrow RCOOH + Energy$

Glucose Lactic acid

Here glucose is broken down to **pyruvic acid.** The pyruvic acid is then reduced to **lactic acid** by $NADH_2$ without the production of carbon dioxide.

First stage: $C_6H_{12}O_6 \longrightarrow 2CH_2COCOOH + 2H^+ +2ATP$

Glucose Pyruvic acid

Second stage: $2CH_2COCOOH \rightarrow CH_2CHOHCOOH + NAD^+ + 2ATP$

Pyruvic acid Lactic acid

Lactic acid occurs in the muscles of animals after every strenuous work or exercise. After is exercise in the muscles, the glucose is broken down to pyruvic acid at a very fast rate, because oxygen is not getting to the muscles cells, the pyruvic acid is reduced to lactic acid in the muscle causes temporary muscle pain or fatigue ache. If enough oxygen later gets to the fatigue muscle cells, it oxidizes the lactic acid to pyruvic acid and the pyruvic acid is oxidized to give carbon dioxide, water and energy.

**Oxygen Debt**

This is the oxygen that is needed to oxidize (burn) lactic to pyruvic acid and from pyruvic acid to car bon dioxide, water and energy.

**Uses of anaerobic respiration**

1. For the fermentation of cassava, guinea corn, locust beans by anaerobic bacteria.
2. Yeast, which is used by the baker respire anaerobic respiratory activity to produce carbon dioxide which makes the dough to rise.
3. During the production of beer, wine and alcohol, yeast is used to ferment sugar to give alcohol.
4. Bacteria decompose the protein that holds the fibers together, thus, the fibers are then processed into linen (bacteria that is used in **retting** of jute respire anaerobically.

**Similarities between aerobic and anaerobic respiration**

1. They both occur in the mitochondria.
2. Both of them break down simple sugar (glycolysis) to pyruvic acid.
3. They both convert pyruvic acid to ATP (energy).
4. Respiratory enzymes and co-enzymes are involved in both forms of respiration.
5. Carbon dioxide is the by-product of both forms of respiration except that lactic acid fermentation which does not produce carbon dioxide.
6. Both reactions produce by-products.

Differences between aerobic and anaerobic respiration

| | Aerobic respiration | Anaerobic respiration |
|---|---|---|
| 1 | Occurs in most plants and animals | Occurs in cells of the muscles, some bacteria and fungi. |
| 2 | Oxygen is needed | Oxygen is not needed |
| 3 | 38 ATP produced | 2ATP produced |
| 4 | $CO_2$ and $H_2O$ are the by-products | $CO_2$ and alcohol or lactic acid are the by- produced |

Differences between photosynthesis and respiration

| | Respiration | Photosynthesis |
|---|---|---|
| 1 | Breakdown of organic matter<br><br>$C_6H_{12}$ O + $6O_2 \longrightarrow$ 6CO + $H_2O$ + energy | Synthesis (building up) of organic matter<br><br>$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$ |
| 2 | $O_2$ is absorbed and used up. | $CO_2$ is absorbed and used up. |
| 3 | Energy ATP is released | Energy in form of heat is released. |
| 4 | $CO_2$ is liberated. | Oxygen is liberated. |
| 5. | Water is liberated | Water is used up. |
| 6 | It takes place in mitochondria | It takes place in chloroplast. |
| 7. | It takes place day and night. | It takes only during the day. |

**Similarities Between Respiration and Photosynthesis.**

- Both of them convert energy from one form to the other.
- They both require mechanism for exchange of gases ($CO_2$ and $O_2$ )
- Both of them involve cycle in respiration and Alvin cycle in photosynthesis.
- They both require specialized organelles (mitochondria for respiration and chloroplast for photosynthesis).
- Both of them processes involve electron carriers (NAI).
- The light reaction of photosynthesis looks like respiration because both expand (use) energy in the form of ATP.

**WEEK 3**

Period 1

ClassSS2

Subject: Biology

Duration: 40 minutes

Topic: Properties and functions of the cell.

Description of content

Photosynthesis: Products, mechanism and importance.

Prerequisite/Prior knowledge

Students have some knowledge of nature matter, chemical symbols, equation, formula, respiration, condition necessary for photosynthesis and importance.

Instructional Objectives:

By the end of lesson the students should be able to:

- Demonstrate the activities to show that oxygen and starch are products of photosynthesis.

- State the mechanism for photosynthesis.
- State the stages of photosynthesis reactions.
- State the importance of photosynthesis.
- Compare photosynthesis and respiration.

Instructional Materials

The materials include green leaf, beakers, test tubes, alcohols, tile, iodine solution, filter paper.

Introduction

Revision of the last lesson is done by the teacher.

Presentation

STEP 1

Teacher asks the following questions:

1. What are the products of photosynthesis?
2. How do we know that the products are starch and oxygen?

STEP 2

Teacher demonstrates the activity to show that oxygen and starch are the products of photosynthesis.

STEP 3

Students observe record and discuss the experiment.

STEP 4

Teacher guides the students to list the products of photosynthesis and explains the mechanism for photosynthesis.

STEP 5

Teacher writes the word equation for photosynthesis and then writes the equation using chemical symbols. The teacher explains the two stages of photosynthesis.

STEP 6

Teacher asks students to list the importance of photosynthesis.

Conclusion

Teacher summarizes the lesson briefly.

Evaluation questions:

1. What are the products of photosynthesis?
2. List the differences between photosynthesis and respiration
3. What are the two stages of respiration?
4. List two differences between photosynthesis and respiration.
5. Why is photosynthesis important?
6. Describe briefly what happens to the carbohydrate that is formed in the leaf.

**Chalkboard Summary**

Define photosynthesis – Photosynthesis is the process where green plants produce carbohydrates. Photosynthesis occurs in two stages – light and dark stages.

A. Light stage

Step 1 – Absorption of light. Chlorophyll absorbs sunlight energy.

Step 2 – Photolysis of water.

The light energy splits the water molecules into hydrogen ($H^+$) and hydroxyl ($OH^-$) ions. The $OH^-$ gives up its electron to chlorophyll molecules to form water and oxygen.

$OH^- + Chlorophyll^+ \longrightarrow Chlorophyll + OH$

$4(OH) \longrightarrow 2H_2O + O_2$

Step 3 – Hydrogen is transferred by NADP. $H^+$ is picked up by NADP (Nicotinamide – adenine dinucleotide phosphate) to form $NADPH_2$

Step 4: Formation of ATP. Chloroplast contain ATP, the extra energy that was not used up in the splitting of water is added to the ADP to form ATP which will be used in dark reaction.

Dark Reaction: (Calvin Cycle)

It is called dark reaction because it does not require light energy. $CO_2$ is reduced by combusting with 2 atoms of hydrogen provided by a coenzyme ($NADPH_2$) to form sugar after going through a series of reactions. ($CO_2$) combines with 2 molecules of hydrogen ($H_2$) to form sugar. The hydrogen is provided by a coenzyme $NADPH_2$. These reactions take place in the chloroplast. The production of glucose is not the end of the reaction (photosynthetic activities). Production or synthesis of fats, oil, proteins and other compounds that are derived from carbohydrate are also produced.

What happens to glucose after it has been produced?

1. Glucose is used by all living cells during respiration for the production of energy.
2. In the presence of sunlight the glucose in the leaves is converted quickly to starch.
3. In the dark (no light) photosynthesis stops and the starch in the leaves is converted to sucrose (a complex sugar) and is taken out of the leaves to other parts of the plant through the phloem vessels.
4. The sucrose is reconverted to starch and stored in organic storage (like

underground stems root tubers, seeds) for later use.

5. If the sucrose is not in excess it is converted into glucose and is used by living cells for respiration or it is used as a starting material for the production of cellulose in plants, proteins, fats and oils and other structural compounds of the living cells.

6. The production of protein, fats and oils involves the absorption of minerals salt from the soil. These mineral salts are incorporated into the organic compounds with the help of enzymes.

Period 2

Class: SS 2

Subject: Biology

Duration: 40 minutes

Topic: Nutrition in animals

Description of content

Carbohydrate- chemical components, tests, and uses

Prerequisite/Prior knowledge- students have some knowledge of atoms, molecules, formula equations, photosynthesis, and respiration; and are familiar with various food substances.

Instructional objective:

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

1. What is a carbohydrate?
2. List the different type of sugar and their formulae.
3. Write the chemical formula for carbohydrate.

4. List the types and number of elements that make up carbohydrate.

5. List some examples of food that are carbohydrate.

Instructional materials

The materials include rice, yam, maize, cassava, bread, chart showing various food items, iodine solution.

Introduction

Teacher asks the following questions:

1. What did you eat this morning?

2. Why did you eat what you ate? (Expected answers- to get energy, to do work, to satisfy hunger, to grow fat, etc.)

3. State the classes of food.

Presentation

Step 1

Teacher displays the chart showing the various food materials and the different food items to the students and the food items are classified into classes.

Step 2

Teacher defines carbohydrate, explains the chemical components of carbohydrates and writes the formula.

Step 3

Teacher explains the types of sugar and their chemical components and writes their formulae.

Step 4

Teacher and students discuss the importance of carbohydrates.

Step 5

Teacher and students test some of the food items with iodine for test of starch

Conclusion

Teacher summarizes the lesson briefly

Evaluation questions:

1. Give five examples of carbohydrate foods.
2. Write the chemical formula for glucose and fructose.
3. What is the general formula for a complex sugar?
4. How would you test for starch in the laboratory?
5. List the classes of carbohydrate.
6. List the importance of carbohydrates.

## Chalkboard Summary

Carbohydrates

Carbohydrates are organic compounds that contain carbon, hydrogen, and oxygen atoms in their appropriate proportions. In all carbohydrates, the ratio of hydrogen to oxygen is 2:1. Examples of carbohydrate are starch, sugar, glycogen and cellulose.

They are classified into

1. Monosaccharides
2. Disaccharides
3. Polysaccharides

Monosaccharides (one molecule sugar)

They are simple sugars with only one molecule of each. They contain 6 or less carbon atoms per molecule. Examples of monosaccharides are glucose ($C_6H_{12}O_6$), fructose ($C_6H_{12}O_6$), ribose $C_5H_{10}O_5$

Disaccharides (Double molecule sugar)

They are complex sugars. Two molecules of simple sugar combine to form disaccharide sugar and water

$$C_6H_{12}O_6 + C_6H_{12}O_6 \longrightarrow C_{12}H_{22}O_{11} + H_20$$

Disaccharide formula is $C_{12}H_{22}O_{11}$

This means

1 molecule of glucose + 1 molecule of fructose = 1 molecule of sucrose

1 molecule of glucose + 1 molecule of glucose = 1 molecule of maltose

(Malt sugar)

1 molecule of glucose + 1 molecule of galactose = 1 molecule of lactose (milk sugar)

Polysaccharide (molecules in chains)

This is a Complex carbohydrate that consists of glucose molecules in a chain. The general formula is $(C_6H_{12}O_6)_n$ where n is a *large* positive integer. Examples of polysaccharides are: starch, glycogen, and cellulose.

1. Sources of Starch include cassava, yam, bread, rice, potato, and so on.
2. Glycogen is a starch stored in the liver and muscle. It is reconverted to glucose when the need arises.
3. Cellulose is formed in the cell walls in most plant cells. Sources of cellulose are vegetables and fruits.

**Importance of carbohydrates**

1. They provide energy (for work) and heat (to maintain body temperature) when they are burnt (oxidized).
2. They act as food reserves (excess carbohydrate is converted to glycogen, stored and reconverted to carbohydrate when the need arises).

3. They provide starting materials for the production (synthesis) of proteins, fats, oils and vitamins.

**WEEK 4**

Period 1

Subject: Biology

Class: SS 2

Duration: 40 minutes

Description of content

Protein - chemistry of protein, constituents and importance.

Prerequisite/prior knowledge:

Students should have some knowledge of chemical symbols, formula, equation and carbohydrates.

Instructional objectives

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

1. List examples of protein.
2. Name the constituents of protein.
3. Write the chemical formula of protein.
4. Perform test for protein.
5. State the uses of protein.

Instructional Materials

Charts, various food items such as meat, fish, egg crayfish, groundnut, beans, test tubes, dilute sodium chloride solution, 1% copper II tetraoxosulphate (VI) solution, water, Mellon’s reagent.

Introduction

Teacher revises the previous lesson.

Presentation

Step 1

Teacher asks these questions to the students:

1. What is protein?
2. Give some examples of proteinous food.
3. How much of proteinous food we eat compared with the quantity of carbohydrate food taken.

Step 2

Teacher and students define protein; explain the chemical components, formula, and importance.

Step 3

Teacher demonstrates the test for protein.

Step 4

Students demonstrate the test, observe, record and discuss their observations.

Conclusion

Teacher briefly summarizes the lesson

Evaluation questions:

1. Define protein.
2. List some examples of protein.
3. Name the elements that make up protein.
4. What are the uses of protein?
5. How can you test for protein?

Assignment

Students are asked to read up fats and oil before the next lesson and read more about protein.

**Chalkboard Summary**

Proteins

Proteins are organic compounds consisting of carbon, hydrogen, oxygen and nitrogen atoms. Some proteins contain little quantities of phosphorous and sulphur atoms.

Protein structure is complex. They consists of chains of amino acid whish are the basic (smallest) units.

Importance of protein

1. Protein is needed for growth.
2. They are used for repair of worn out or damaged tissues.
3. Proteins are used to make enzymes.
4. They give certain amount of energy.
5. They are used to make white blood cells and antibodies.

The lack of protein in the diet of a growing child leads to kwashiorkor (a disease of protein deficiency in diet). A child with the disease has;

- Retarded growth
- Weak muscles
- Swollen legs
- Loss of weight
- Change of hair colour from usually black to brownish red.

Period 2

Subject: biology

Class: SS 2

Topic: Nutrition in animals

Duration: 40 minutes

Description of content

Lipids (fats and oil) - constituents and importance.

Prerequisite/prior knowledge

Students have some knowledge of carbohydrate, protein, chemical symbols, formula, test for fats and oil.

Instructional objective

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

1. Explain the meaning of lipids.
2. Differentiate between fats and oils.
3. List the constituents of fats and oils.
4. State the uses of fats and oil.
5. Test for fats and oil

Instructional materials

Vegetable oils, groundnut, coconut, melon, kernel and palm fruit oils, butter, margarine.

Introduction

Teacher revises the last lesson.

Presentation

Step 1

The various samples are presented to the students asking these questions:

1. What are lipids (fats and oils)?
2. What is the difference between fats and oils?
3. What elements make up fats and oils (lipids)?
4. What is the importance lipid?

Step 2

After answering the questions, lipid is defined and the constituent of lipid (chemical make- up) and importance are discussed by the teacher and students.

Step 3

Teacher demonstrates test for lipids.

Step 4

Students demonstrate the test for lipids, observe, and record their findings.

Conclusion

Teacher summarizes the lesson briefly.

Evaluation questions:

1. What is a lipid?
2. List the elements that make up fats and oils.
3. What is the difference between fats and oils?
4. What is the importance of fats and oils?

**Chalkboard Summary**

Fats and oil (lipids) are organic compounds containing carbon, hydrogen, and oxygen atoms. They contain high proportion of carbon and hydrogen and a little oxygen.

Difference between fats and oils

| Fats | Oils |
| --- | --- |
| Solid at room temperature | Liquid at room temperature |

Liquid fats are called oil. Fats and oil are not soluble in water, but soluble in solvents like kerosene, ether, chloroform and benzene.

Oils can be got or extracted from plants and animals by the process of heating. The oils can be hardened to form butter by cooling, freezing, and hydrogenation.

Importance of lipids (fats and oils)

1. They yield more energy than carbohydrate when burnt (oxidized).
2. Fats help to keep the body warm and protect delicate organs by storing excess fats under the skin and around some organs like intestine, eyes, gonads (reproductive organs) kidneys and heart.

Period 3

Subject: biology

Class: SS 2

Topic: Nutrition in animals

Duration: 40 minutes

Description of content

Enzymes - definition and functions.

Instructional objectives

By the end of the lesson, students should be able to

1. Define enzymes.
2. List the classes of enzymes.

3. State the characteristics of enzymes.

Introduction

Revision of the last lesson

Presentation

Step 1

Teacher asks the following questions:

1. What are enzymes?
2. What are the characteristics of enzymes?
3. What are the classes of enzymes?
4. List some types of enzymes.

Step 2

Teacher guides the students to answer the questions.

Step 3

Teacher makes clearer some of the not well-answered points to the students.

Conclusion

Teacher summarizes the lesson briefly.

Evaluation questions

1. Define enzyme.
2. List some examples of enzymes and their functions
3. What are the classes of enzymes?
4. What are the characteristics of enzymes?

## Chalk Board Summary

Enzymes

Enzymes are organic catalysts of protein origin. They are produced by living cells. They speed up or alter the rate of biochemical reaction but remain chemically unchanged at the end of the reaction.

Classes of enzymes

Enzymes are classified according to their functions and type of food they act on. They are classified into three groups- amylase, protease, and lipases

Amylases - act on carbohydrates (starch and complex sugar). Examples of amylase are sucrase, lactase, and ptyalin.

Maltase - changes maltose to glucose.

Sucrase changes sucrose to glucose and fructose.

Lactase changes lactose to galactose and glucose.

Ptyalin changes starch to maltose sugar.

Proteases

They act on proteins, changing them into amino acids. Examples of proteases are pepsin, trypsin, renin, and erypsin.

Pepsin changes protein to peptones.

Renin coagulates milk protein.

Trypsin changes proteins to peptones.

Erepsin changes peptones to amino acids

Lipases acts on fats and oils changing them to fatty acids and glycerol

Characteristics of enzymes

1. Speeds up or slows down the rate of reaction (within the body of the organisms).
2. They remain chemically unchanged at the end of the reaction.
3. They are specific in their action.
4. They are required in small quantity.
5. They are best over a small range of temperature.

6. They are pH specific (acidity and alkalinity) and act best at certain levels of pH.
7. Most enzymatic actions are irreversible.
8. Enzymes are retarded by poison or inhibitors.
9. Enzyme can function outside the body of the organism that produces them.

**APPENDIX III**

**Test of Students Understanding of Chemical Concept (TOSUCC)**

**<u>Section A</u>**

Complete this section before section B

Class: SS 2

Sex: male ☐ female ☐

Town:…………………………………………………………………………..

**<u>Section B</u>**

**<u>Instruction</u>**

Answer all questions

1. Write three examples each of physical and chemical change.

2. List any three differences between chemical and physical changes.

3. Write any two differences between mixtures and compounds.

4. A. List any two characteristics of a physical change.

B. Define the term valency?

5. A. Given the atomic masses Na = 23 and Cl = 35.5, find the molar mass of sodium chloride NaCl

   B. Find the molecular weight of aluminum tetraoxosulphate IV $(Al_2SO_4)_3$. (Al = 27, S = 32, O = 16).

6. Define matter.

7. List the three states of matter.

8. State the particulate theory of matter.

9. List the two elements that make up water.

10. What is matter made up of?

11. Why are the elements argon and helium said to be noble?

12. An atom that has either gained or lost electron is called an ……………………?

13. List any three (3) chemical compounds of your choice.

14. When an atom gains or receives electron it becomes an …………….ion?

15. Write the symbol of any four common elements you know.

16. What are the charges for electron, proton and neutron?

17. Write the chemical formula for sodium chloride.

18. Draw a diagram to show the electron arrangement in the K, L, and M shell of sodium.

19. Three molecules of carbon (IV) oxide contains………………..atoms of oxygen?

20. …………..is made up of two or more substances chemically combined together?

21. List two characteristics of chemical change.

22. If an element X has valency 2 and Y has valency 3, the formula of the compound formed by X and Y is…………….?

23. List three examples of mixtures.

24. Balance this equation

$$Fe + O_2 \longrightarrow Fe_3O_4$$

25. Write the chemical formulae for hydrochloric acid, tetraoxosulphate (VI) acid, and sodium hydroxide.

**APPENDIX IV**

**Biology Achievement Test (BAT)**

**<u>Section A</u>**

Complete this section before going to section B

<u>Class </u>- SS2

<u>Sex: </u>male ☐ female ☐

<u>Town</u>: ……………………………………………………………………..

**<u>Section B</u>**

1. State any two characteristics each of:
   a. Osmosis
   b. Diffusion in plants and animals
2. a. What is photosynthesis?
   b. Outline the processes involved in light and dark reactions briefly.
   c. What is the importance of photosynthesis in nature?
3. a. What is?
      i. Aerobic respiration?
      ii. Anaerobic respiration?
   b. What is the importance of ATP?
4. a. State one difference between fats and oils.
   b. List 5 common food substances rich in carbohydrates
   c. What are the elements that make up fats and oils?
5. a. List two characteristics of enzymes
   b. State two differences and similarities between respiration and photosynthesis.
6. The bursting of red blood cells in the plasma is……………………?

7. What is the chemical formula for carbohydrate?

8. Mention two factors that speed up the rate of diffusion.

9. The raw materials for photosynthesis are …………and …………….

10. The products of photosynthesis are ………….., …………………., and ……………..

11. List two factors that affect photosynthesis

12. Write the equation for photosynthesis.

13. Define osmosis.

14. The reactants in cellular respiration are…………… and ……………

15. What are the products of respiration?

16. Deficiency of protein in children between the ages of one to five is……………..?

17. The elements that make carbohydrate are …?

18. The site for cellular respiration in the cell is………………?

19. List two characteristics of enzymes.

20. Name the substances that accumulate in the muscles of athletes after a keenly contested 400metres race.

21. List three enzymes and what they digest

22. In what part of the cell do the series of reaction for the kreb's cycle take place?

23. Kreb's cycle was discovered by a Biochemist called…………….?

24. Another name for kreb's cycle is……………….?

25. Write out the full meaning of ATP

**APPENDIX V**

**Solutions/Marking Scheme for the Test of Student Understanding of Chemical Concepts (TOSUCC)**

Q1. a. Physical changes

I. Mixing of sand and salt

II. Mixing of salt and sand

III. Changing the shape of a wet clay

IV. Bending of a piece of metal

V. Melting of wax

VI. Solidify wax by cooling

b. Chemical changes

I. Burning of a piece of paper

II. Burning of candle wax

III. Burning of a piece of paper

IV. Cooking a pot of stew

V. Burning of wood

VI. Rusting of nail

Q2.

| Physical | Chemical |
|---|---|
| No new substance is formed | New substance is formed |
| The change is easily reversible | The change is almost irreversible |
| It is not always accompanied by heat | Always accompanied by heat |
| No change in mass | The new products have different masses, but the aggregate mass remains |

| | |
|---|---|
| | the same |
| The mixture formed cannot be represented by a single chemical formula | The products can be represented by a chemical formula |
| Does not require activation of energy | It requires activation of energy |

Q3.

| Mixture | Components |
|---|---|
| The constituent substance are physically combined | Constituent elements are chemically combined |
| It is easily reversible by chemical methods | It is almost irreversible |
| It can be mixed in any proportion | It must obey the law of definite proportion |
| It cannot be reduced to single chemical formula | It can be reduced to a single formula |

Q4 a

I. No new substance is formed

II. Changes are easily reversible

III. It is not accompanied by heat

IV. No change in mass

b. Valency combining power on element

Q5

a. 23 + 35.5 = 58.5

b. (27 * 2 + 32 + 16 * 4)3 = (54 + 32 +64)3 = (150)3 = 450

Q6 Anything that has mass and occupies space

Q7 Solid, liquid and gas

Q8 Matter is made up of tiny particles

Q9 Oxygen, Hydrogen

Q10 Matter is made of tiny particles called atoms

Q11 The electrons in the outermost shells are complete

Q12 Ion

Q13 Water, Carbon (IV) oxide, Calcium carbonate, Calcium Chloride, Sodium chloride, Hydrochloric acid

Q14 Electronegative ion

Q15 H, C, S, He, Na, etc.

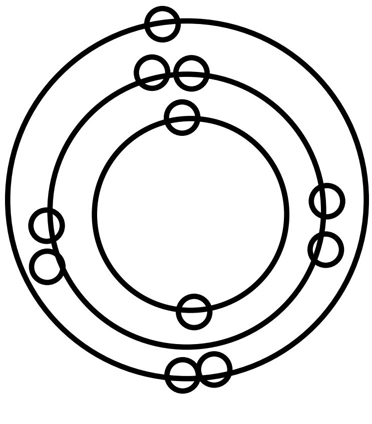
Q16 Electron – negative charge

Proton – Positive charge

Neutron – No charge

Q17 NaCl

Q18



Q19 6 Atoms of oxygen

Q20 Compound

Q21 a. Not reversible

b. Produces heat

c. New substance is formed

Q22 $X_3Y_2$.

Valency of X = 2, valency of Y = 3

Q23 sand and rice, air, sea water, rice and beans

Q24 $3Fe + 2O_2 \longrightarrow Fe_3O_4$

Q25 HCl, $H_2SO_4$, NaOH

**APPENDIX VI**

**Solutions to Biology Achievement Test (BAT)**

Q1a.

I. Absorption of water from soil into the vacuoles of the root hair

II. Movement of water molecules from the root hair to the cells of the cortex

III. Opening and closing of stomata

IV. Give turgidity to plants

V. Reabsorption of water in kidney of mammals

VI. Absorption of water from

VII. Haemolysis of red blood cells is by osmosis

b.

I. Movement of air in the intercellular spaces in flowering plants

II. Mineral salts in soil enter the root through the process of diffusion

III. $CO_2$ and $O_2$ enter the plant leaves through the process of diffusion

IV. Exchange of gases during respiration is by diffusion.

V. Digested food are passed to the blood stream during diffusion

VI. Digested food enter the saprophytic plants through the process of diffusion

Q2. a. Photosynthesis is the process whereby green plants produce carbohydrate in the presence of light

b. Light stage

Step 1 – Absorption of light – chlorophyll absorbs sunlight energy

Step 2 – Phytolysis of water – Water molecules split into $OH^-$ and $H^+$ to form water and oxygen later

Step 3 – Hydrogen transferred to NADP to form $NADPH_2$

Step 4 – Formation of ATP

Dark Reaction (Calvin's Cycle)

Reduction of $CO_2$ to form carbohydrate and subsequent synthesis of carbohydrates

c. Importance of Photosynthesis

I. All living things need energy for growth and metabolism. This energy comes from photosynthesis
II. Oxygen, a product of photosynthesis is necessary for respiration
III. Purifies the atmosphere
IV. Provides fuel, building materials, clothes and fabrics
V. Glucose, a product of photosynthesis is the start point for the synthesis of protein
VI. Helps to clear $CO_2$ from the environment.

Q3. a. Aerobic respiration is the process whereby glucose is broken down by oxygen to produce carbon dioxide and water and energy is released.

b. Anaerobic respiration (alcoholic fermentation) is the type of respiration in which glucose is broken down in the absence of oxygen to produce alcohol, $CO_2$ and 2 ATP.

c. Importance of ATP

I. All living things require energy to do work
II. ATP required for the synthesis of
III. It is requires for cell division

Q4. a.

| Fats | Oils |
|---|---|
| Solid at room temperature | Liquid at room temperature |

b. Rice, bread, indomie, yam, potatoes, cassava, etc.

c. Carbon, hydrogen and Oxygen

Q5a

| Respiration | Photosynthesis |
|---|---|
| Breakdown of organic matter | Synthesis (build-up) of organic matter |
| $O_2$ ion absorbed and used up | $CO_2$ is absorbed and used up |
| ATP is released | Energy in form of heat |
| $CO_2$ is liberated | Oxygen is liberated |
| Takes place in mitochondria | Takes place in chloroplast |
| Takes place day and night | Takes place during the day |
| Water is hydrated | Water is used up |

b. <u>Similarities</u>

Both convert energy from one form to the other. Both require mechanism for exchange of gases ($CO_2$ and $O_2$).

Both require special organelles – mitochondria for respiration and chloroplast for photosynthesis.

Both processes involve electron carrier.

Q6 Haemolysis (busting of red blood cell in the plasma)

Q 7 $C_6H_{12}O_6$

Q 8

I. Heating or increase in temperature.

II. Shaking or stirring.

Q 9 Water and Carbon (IV) oxide

Q10 Carbon (IV) oxide, water and oxygen

Q11 Light, Chloroplast

Q12 $6CO_2 + 12H_2O$ + light $\rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$

Q13 Osmosis is the movement of water molecules from a region of lower concentration to a region of higher concentration through a semi-permeable membrane

Q14 Glucose + Oxygen

Q15 Carbon (IV) oxide and water

Q16 Kwashiorkor

Q 17 Carbon, hydrogen, oxygen

Q18 Mitochondria

Q19 Speed up chemical reaction, specific in action, does not change at the end of a reaction

Q20 Lactic acid

Q21 Pepsin - protein

Renin - curdles milk

Maltose - Malt

Sucrose - Sucrose

Ptyalin - Carbohydrate i.e. cooked starch

Q22 Mitochondria

Q23`Hans Krebs

Q24 Citric acid cycle

Q25`Adenosine triphosphate

**APPENDIX VII**

**Lists of Schools for the Study**

| **S/N** | **NAME OF SCHOOL** | **SENATORIAL DISTRICT** |
|---|---|---|
| 1. | Ime-Obi Secondary School Ime-Obi, Agbor. | DELTA NORTH |
| 2. | St. George Grammar School, Obinombia. | |
| 1. | Abraka Grammar School, Abraka. | DELTA CENTRAL |
| 2. | Baptist high School, Eku | |
| 1. | Agbarho Grammar School, Ughelli. | DELTA SOUTH |
| 2. | Our Ladies Girls High School, Effurun. | |

**APPENDIX VIII**

Institute for Science and Technology Education (ISTE)
University of South Africa,
Pretoria.
8th October, 2013.

The Principal

**REQUEST FOR USE OF YOUR SCHOOL FOR RESARCH STUDY**

I am Ikhifa Grace, a doctoral student at the Institute for Science and Technology Education, University of South Africa (UNISA), Pretoria.

As part of my thesis requirements, I would be conducting a research on 'The Effects of Chemical Concept Understanding Level on Students' Achievement in Biochemical Topics' with your school as part of my research sample schools. Six schools from the three senatorial districts of Delta State would be used for the study and your school has been chosen as one of them.

This letter is to request for your permission to use your school for data collection processes of the study. The data to be collected would be kept confidential and participants' names would not be attached to any part of the thesis. Students' participation in the study would be voluntary, and any participant is free to withdraw from the research activity at any point without any form of penalty.

Thank you for your anticipated consideration and cooperation.

Yours faithfully,

Ikhifa Grace O.

## APPENDIX IX

### Informed Consent For participants

I am Grace Ikhifa, a doctorate student at the Institute for Science and Technology Education, University of South Africa, Pretoria. You are kindly requested to participate in an 8-week teaching and learning session on chemical concepts (physical and chemical change, elements compounds, valency, chemical symbols, chemical formulae, simple equation and molecular structure) and biochemical topics (photosynthesis, cellular respiration, carbohydrates, proteins, fats and oils and enzymes) for a research study.

The purpose of the study is to find out The Effects of Students Chemical Concept Understanding Level on Their Achievement in Biochemical Topics.

Confidentiality

Data collected would be kept confidential as no name would be attached.

Benefits

Findings of this study would be of benefit to students since it would help to increase their level of academic achievement.

Participation

Your participation in this study is voluntary; you may refuse to participate without penalty. If you decide to participate, you can withdraw from the study at any time without penalty.

Contact

If you have questions at any time about the study, you may contact the researcher.

Name: Ikhifa Grace

Address: Integrated Science Department, College of Education, Agbor

Phone: 07038081690

E-mail:ikhifagraceo@yahoo.co.uk

Consent: I have read and agreed to take part in this study.

Participant`s signature………………………….. Date………………

**APPENDIX X**

**Table of Specification for Test Items for Test of Student Understanding of Chemical Concept (TOSUCC)**

| | **Knowledge** | **Comprehension** | **Application** | **Total** |
|---|---|---|---|---|
| Matter | 2 | 2 | 1 | 5 |
| Physical//Chemical changes | 1 | 2 | 2 | 5 |
| Element, compound and Mixture | 2 | 1 | 2 | 5 |
| Chemical symbol/Valency | 2 | 2 | 1 | 5 |
| Chemical formula/Simple equation | 1 | 2 | 2 | 5 |
| **Total** | | | | **25** |

**APPENDIX XI**

**Table of Specification for Test Items for Biology Achievement Test (BAT)**

| | Knowledge | Comprehension | Application | Total |
|---|---|---|---|---|
| Diffusion/ Osmosis | 1 | 2 | 2 | 5 |
| Respiration | 2 | 1 | 2 | 5 |
| Photosynthesis | 2 | 2 | 1 | 5 |
| Enzymes | 1 | 1 | 2 | 5 |
| Carbohydrate/ Protein/Fat | 2 | 2 | 1 | 5 |
| Total | | | | 25 |

## APPENDIX XII

### Training Package for Research Assistants

Twenty (20) research assistants with B.Ed. /B.Sc. and PGDE/NCE qualification in chemistry/Biology/Integrated Science were trained for one day.

The researcher went to the teachers in their various schools to do the training with them. The purpose of the training was to

1. Explain the aims and objectives of the research.
2. Explain the research design outlined.
3. Scrutinize data collecting instrument thoroughly by
    a. Researcher explaining the lesson plans and chalk board summary to the trainees.
    b. Assessing the trainees with the Achievement Test items.
    c. The researcher and the trainees going through the test items and answers together.
    d. Picking the best from the test results.
    e. Giving the trainees the lesson plan and test items before the commencement of the research study for them to be very well acquainted with the instruments.

This training was made possible with the permission of the various school principals.

**Training Program for Research Assistants**

A - One day training program for Research Assistants: For data collection on research study on Effects of Students Chemical Concepts Understanding Level on their Achievement in Biochemical Topics.

<u>Outline</u>

1. Explanation of the aims and objectives of the study.
2. Explanation of the research design.
3. Going through the lesson plans with assistants and explanation of the chalkboard summaries of each of the topics.
4. Assessment for Research Assistants
   - i. What are the aims and objectives of the study?
   - ii. What is the research design?
   - iii. Questions from the test items for Achievement Tests of Students Chemical Concept Understanding and Biology Achievement Test would be administered to the assistants for discussions during the training.

5. Review of the Test items for necessary corrections.

## APPENDIX XIII

### List of Acronyms

NCE – National Certificate of Education

JSS – Junior Secondary School

SSS – Senior Secondary School

B. Ed – Bachelor of Education

B. Sc. – Bachelor of Science

TOSUCC – Test of Students Understanding of Chemical Concepts

BAT – Biology Achievement Test

PGDE – Post Graduate Diploma in Education

**APPENDIX XIV**

**INTERVIEW SCHEDULES AND FIELD NOTE**

Date: 24/9/2014

Time: 10:00AM

**Physical Setting:** Office of the head of Biology Department.

**Teacher I**

**Interviewer**

- Good afternoon madam,

  I am pleased that you have accepted to participate in this interview.

  This interview is for the purpose of research and will not be used against you or anyone in any way.

- *Question:* Madam how long have you been teaching the subject, Biology?

**Interviewee`s response:**

- *Fifteen years*

**Interviewer**

- *Question:* Are you familiar with concepts like chemical and physical concepts, elements, compounds and mixture and so on, and Biochemistry topics like photosynthesis, respiration, carbohydrate, protein, fat, and enzymes?
- The interest in this interview is to find out
  - the level of students understanding of chemical concepts
  - How understanding of chemical concepts affects the understanding and achievement of the biochemical topics mentioned earlier.
- What is the level of students understanding of chemical concepts of physical

and chemical changes?

**Interviewee`s responses:**

- *Hmmm.., I am really familiar with these topics.*
- *Well, student's understanding of physical and chemical changes is okay, however the students find it easier to understand physical changes than chemical changes.*

**Interviewer**

- How can you rate their understanding of elements as a topic?

**Interviewee`s responses:**

- *Yeah, students find it not so easy to understand elements, since they cannot see most of them.*
- *Students require further and careful teachings to enable them understand elements*.

**Interviewer**

- There are other concepts of interest in this research such as compounds and mixtures. What is the students' level of understanding of these concepts?

**Interviewee`s responses:**

- *Hmm! They find it not so easy to understand compounds as a concept, but it is very easy for them to understand mixtures and they can relate with it. I think it is because the students find the formation and separation of mixtures as part of their everyday experiences.*

**Interviewer**

- Do your students find it easy to understand chemical symbols and valency as topics?

**Interviewee`s responses:**

- *Mm mm…, just like in the case of compounds, the students also find it difficult to understand chemical symbols and valency, and teaching these concepts requires patience from the teacher.*
- *In writing chemical symbols, students get confused, as the symbols seem to be difficult because the symbols are in letters.*

**Interviewer**

Would you think there is anything special to effectively teach chemical concepts? If yes, what could it be?

**Interviewee`s responses:**

- *Yes! There are issues about these chemical concepts. A child once asked in the class why the symbol "Na" is used for sodium.*
- *In fact, these chemical concepts (chemical symbols and valency) require more skills to teach in order for students to gain understanding.*

**Interviewer**

- What about chemical formula and molecular structure? How do the students perceive concepts?

**Interviewee`s responses:**

- *Ah! Chemical formulae are more difficult for students to understand and complain much about concept. So we move from word symbols to chemical symbols with the hope of making the students catch up with the expected level of understanding of the concept.*
- *For molecular structure, the learners have to resort to memorizing them to be able to learn. They do not find it easy either.*

**Interviewer**

- You have been teaching for a while, can you briefly tell how students' understanding of chemical concepts affect their understanding of biochemical topics like photosynthesis, respiration, diffusion and osmosis, carbohydrate, proteins, fats and enzymes.

**Interviewee`s responses:**

- *Yeah! The understanding of biochemical topics is influenced by the understanding of chemical concepts. My experience has shown that the science students who have better exposure to chemical concepts find it easier to learn the biochemical topics because of the inter-relatedness of the concepts and topics.*

**Interviewer**

- What can you say about student's achievement in these topics? Does the understanding of chemical concepts lead to higher achievement level in the biochemical topics?

**Interviewee`s response:**

- *Yes, an adequate understanding of chemical concepts brings about higher level of students` achievement in biochemical topics.*

**Interviewer**

- How do you relate the topic of "Kreb`s Cycle" to the students in the class?

**Interviewee`s response:**

- *In the teaching of Kreb`s cycle in respiration and digestion of food substances needs to be taught as required by the syllabus, relating it to such elements as Hydrogen, Oxygen and Carbon.*

**Interviewer**

- Does the understanding of chemical concepts affect the students' knowing of Kreb's cycle or makes no difference?

**Interviewee`*s responses:***

- *Yes it does. The entire nature of Kreb`s Cycle is about chemical concepts that require good understanding in order to comprehend Kreb`s Cycle and the process.*

**Interviewer**

- What is the students' general level of understanding of the chemical concept?

**Interviewee`s response:**

- *Very good,… but the science students with the prior knowledge of chemical concepts from their lower classes show better understanding of biochemical concepts at senior class level compared with those without such fundamental knowledge.*

**Interviewer**

- Thank you very much for your time and co-operation in answering the interview questions.

**TEACHER 2**

**Interviewer**

- Thank you for accepting to participate in this study as you have been earlier informed, this research will not in any way harm you or your students and the result will be used for research purpose only.

**Interviewee**

- *Thank you.*

**Interviewer**

- How would you rate students understanding of physical and chemical changes and other chemical concepts that are related to biochemical topics you teach?

**Interviewee`s response**

- *As students are taught chemical change and exchange of valency, it seems abstract to them and more effort need to be made to help their understanding. But this is not exactly so with physical change, they can easily relate with it.*

**Interviewer**

- What about such topics like elements, compounds and mixtures?

**Interviewee`s response**

*Well, the students find them difficult even though they eventually learn.*

**Interviewer**

- It seems as if chemical changes are more difficult to learn than the physical changes. Does the understanding of these concepts help students to better learn biochemical topics?

**Interviewee**

- *Yes, chemical changes are more difficult to learn than physical changes. Yet, the understanding of chemical concepts aid students understanding of biochemical topics.*

**Interviewer**

- Does the level of understanding also have effect on students' achievements? What is the reason for your answer?

**Interviewee`s response**

- *It does!*

- *In the case of the science students who do chemistry in senior secondary school I (equivalent to grade 10), they do not only find it easier to understand biochemical topics, but also achieve better than the other students.*

**STUDENT I**

**Interviewer**

- Thank you for accepting to participate in this research interview. This interview is for the purpose of research. It is not to tag anyone or rate anyone.
- There are some chemical concepts that you would have been exposed to by now. I will ask you one after the other while you tell me if you find any of them difficult or easy or not so difficult to understand.
- Did you find it easy to study concepts like physical and chemical changes? Did you understand them?

**Interviewee`s response**

- *Yes sir*

**Interviewer**

- What about elements?

**Interviewee`s response**

- *Yes*

**Interviewer**

- What about compounds?

**Interviewee`s response**

- *Yes.*

**Interviewer**

- What of mixtures?

**Interviewee`s response**

- *Yes.*

**Interviewer**

- How would you compare your understanding level for physical and chemical changes? What one characteristic each can you give for these concepts?

**Interviewee`s response**

- *Both of them are actually easy.*
- *Ok, physical change is reversible, but the chemical change is not reversible.*

**Interviewer**

- How do you rate the concepts like valency, chemical symbol, and chemical formulae in terms ease of understanding?

**Interviewee`s response**

- *When you start to learn them, they are difficult at first, but as you get used to them and use them all the time, they become easier.*

**Interviewer**

- What about chemical formula and molecular structure and atomic structure?

**Interviewee`s response**

- *They are good and I enjoy reading them up and doing things about and around them.*

**Interviewer**

- Did you find the knowledge of these chemical concepts useful when learning photosynthesis?

**Interviewee`s response**

- *Yes, very useful.*

**Interviewer**

- Was the knowledge of these chemical concepts useful when learning of respiration, diffusion and osmosis?

**Interviewee`s response**

- *Certainly yes.*

**Interviewer**

- Did you find a link between the concepts?

**Interviewee`s response**

- *Not really.*

**Interviewer**

- What about carbohydrate, protein, fats, and enzymes?

**Interviewee`s response**

- *Yes*

**Interviewer**

- Do you consider that knowledge of these chemical concepts helped your learning and understanding of Kreb's cycle in respiration?

**Interviewee**

- *Now, we are in SS2 (Senior Secondary School Two), what we are doing in chemistry has helped us to understand Kreb's cycle, when you read Kreb's cycle and all these topics you are talking about, you will really know their formula which helps you to better understand Kreb`s cycle.*

**Interviewer**

- Are you able to get better scores as a result of these learning?

**Interviewee`s response**

- *Yes*

**STUDENT 2**

**Interviewer**

- Thank you for accepting to participate in this study. It is for research purposes only.
- It is to find out the influence of prior knowledge some chemical concepts on students learning and understanding of some biology topics.
- Do you find the study of Physical and chemical changes concepts easy or difficult?

**Interviewee`s response**

- *They were easy to me.*

**Interviewer**

- What about the study of compounds, mixtures and elements?

**Interviewee**

- *They were also easy to me.*

**Interviewer**

- Thinking about valency, chemical symbol, simple equation and atomic structure, what can you say in terms of the ease of understanding them?

**Interviewee`s response**

- *They were all easy. They were all easy, but some were much easier. But the one I found not so easy was writing a chemical formula, chemical equation and memorizing the symbols of chemicals.*

**Interviewer**

- Did the understanding of these chemical concepts help you in understanding biochemical topics like photosynthesis?

**Interviewee`s response**

- *Yes.*

**Interviewer**

- What about respiration?

**Interviewee`s response**

- *Yes.*

**Interviewer**

- What can you say of diffusion and osmosis?

**Interviewee`s response**

- *Yes, but for diffusion, I didn’t really find a link between diffusion in chemistry and diffusion in biology.*

**Interviewer**

- What about carbohydrate, protein, fats and enzymes

**Interviewee`s response**

- *Yes.*

**Interviewer**

- Did you find the knowledge of chemical concepts as an aid in the understanding of Kreb’s cycle in respiration?

**Interviewee**

- *Yes.*

**Interviewer**

- If you didn’t have knowledge of chemical concepts, would your understanding of Kreb’s cycle be possible? Give reason for your answer.

**Interviewee`s response**

- *No! It wouldn't have been possible. This is because Kreb`s cycle has a lot of chemical concepts related to it.*

**Interviewer**

- In essence a good understanding of these chemical concepts also translates to a better understanding of Kreb's cycle in respiration.

**Interviewee`s response**

- *Yes.*

**Interviewer**

- Would you consider your understanding of these chemical concepts to have helped you to achieve better scores in biology related areas?

**Interviewee`s response**

- *Certainly yes.*

**Interviewer**

- Thank you very much, you have been quite helpful and I appreciate your honest answers.

**Interviewee`s response**

- *Thank you too.*

**STUDENT 3**

**Interviewer**

- Thank you for accepting to participate in this study. The interest of the study is to find out how the prior knowledge of some chemical concepts influences the understanding of some biology related topics like photosynthesis, respiration and others.
- Did you find it difficult to learn about physical and chemical changes?

**Interviewee`s response**

- *Not at all.*

**Interviewer**

- What about elements, compounds, mixtures, valency, chemical symbols, chemical formula, molecular structure and simple equation?.

**Interviewee`s response**

- *I find them very easy.*

**Interviewer**

- Is there any among these concepts you found much easier than others?

**Interviewee**

- *Mmmh yes! Valency was much easier to understand than other topics.*

**Interviewer**

- What about chemical symbols formulae?

**Interviewee`s response**

- *It was quite easy, because you still need valency to be able to write it.*

**Interviewer**

- Did your learning of chemical concepts help you to understand such concepts like photosynthesis, respiration in biology?

**Interviewee`s response**

- *Yes, also in respiration.*

**Interviewer**

- Did you see a link between these chemical concepts and diffusion and osmosis in biology?

**Interviewee`s response**

- *Yes, like when our teacher brought eosin to the class to show diffusion in water. Eosin is a chemical substance and by bringing it to biology class to demonstrate diffusion shows the relationship between chemistry and biology.*

**Interviewer**

- Do you think that carbohydrate, protein, fats, and enzymes have relationship with chemical concepts?

**Interviewee`s response**

- *Yes.*

**Interviewer**

- Do you consider your prior learning of these chemical concepts influenced your achievement in biology?

**Interviewee`s response**

- *Yes, it did*

**Interviewer**

- Did such prior learning help your understanding of Kreb's cycle?

**Interviewee`s response**

- *Yes, it did*

**Interviewer**

- Which means you can say that a good understanding of these chemical concepts influenced your understanding of biology?
- **Interviewee`s response**
- *Yes! Very well.*

**Interviewer**

- Thank you very much, nice to have you.

**Interviewee`s response**

- *Thank you ma, you are welcome.*

**STUDENT 4**

**Interviewer**

- Thank you very much for accepting to participate in this study. It is for the purpose of research study only. Evidently, you are contributing to knowledge by participating.

**Interviewer**

- How would you rate your understanding of concepts like physical and chemical changes?

**Interviewee`s response**

- *Just a little bit*

**Interviewer**

- How is your understanding level considering carbohydrate, protein, fats and enzymes?

**Interviewee`s response**

- *Excellent ma.*

**Interviewer**

Would you consider your knowledge of chemical concepts to have helped you in the understanding of Kreb's cycle?

**Interviewee`s response**

- *Hmmm…, Not really.*

**Interviewer**

- Consider your achievement in biology related topics. Did your knowledge of chemical concepts help your better achievement in biology?

**Interviewee`s response**

- *Oh Yes!*

**Interviewer**

- You consider that if you hadn't the knowledge of these chemical concepts, you may have had difficulty in understanding the biology.

**Interviewee`s response**

- *Yes of course.*

**Interviewer**

- Thank you very much, you have been so wonderful. I appreciate your contribution and all that you have said. Thank you for participating.

**Interviewee`s response**

*You are welcome Ma!*

**APPENDIX XV**

UNISA | college of science, engineering and technology

Ikhifa Grace Onyenenue (49042483)
College of Science, Engineering and Technology
UNISA Johannesburg

**2014-02-14**

**Permission to conduct research project**

**Ref: 005/IGO/2014**

**The request for ethical approval for your PhD (MST) Science Education research project entitled "Effects of students' chemical concept understanding level, on their achievement on Bio-Chemical Topics" refers.**

**The College of Science, Engineering and Technology's (CSET) Research and Ethics Committee (CREC) has considered the relevant parts of the studies relating to the abovementioned research project and research methodology and is pleased to inform you that ethical clearance is granted for your study as set out in your proposal and application for ethical clearance.**

**Therefore, involved parties may also consider ethics approval as granted. However, the permission granted must not be misconstrued as constituting an instruction from the CSET Executive or the CSET CREC that sampled interviewees (if applicable) are compelled to take part in the research project. All interviewees retain their individual right to decide whether to participate or not.**

**We trust that the research will be undertaken in a manner that is respectful of the rights and integrity of those who volunteer to participate, as stipulated in the UNISA Research Ethics policy. The policy can be found at the following URL:**
**http://cm.unisa.ac.za/contents/departments/res_policies/docs/ResearchEthicsPolicy_apprvCounc_21Sept07.pdf**

**Please note that if you subsequently do a follow-up study that requires the use of a different research instrument, you will have to submit an addendum to this application, explaining the purpose of the follow- up study and attach the new instrument along with a comprehensive information document and consent form.**

**Yours sincerely**

**Chair: College of Science, Engineering and Technology Ethics Sub-Committee**

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