IMPACT OF 5Es PROBLEM-SOLVING MODEL ON SCIENCE PROCESS-SKILLS ACQUISITION,PERFORMANCE AND RETENTION IN CELL PHYSIOLOGY AMONG SECONDARY SCHOOL BIOLOGY STUDENTS, ZARIA, NIGERIA

BY

Sadiq USMAN

B.Sc (Ed.) Biology (A.B.U., 2015)

P16EDSC8074

DEPARTMENT OF SCIENCE EDUCATION,

FACULTY OF EDUCATION,

AHMADU BELLO UNIVERSITY,

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Sadiq USMAN
B.Sc (Ed.) Biology (A.B.U., 2015)
P16EDSC8074
dusmans0002@gmail.com

A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER DEGREE IN BIOLOGY EDUCATION

DEPARTMENT OF SCIENCE EDUCATION,

FACULTY OF EDUCATION,

AHMADU BELLO UNIVERSITY,

ZARIA, NIGERIA

MARCH, 2021

DECLARATION

I hereby declare that this dissertation entitled, "Impact of 5Es Problem-Solving Model on Science Process-Skills Acquisition, Performance and Retention in Cell Physiology among Secondary School Biology Students, Zaria, Nigeria", is written by me. It is a record of my own research and has not been presented in any previous application for a higher degree. All quotations and sources of information are fully acknowledged by means of references.

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Sadiq, USMAN
P16EDSE8074

Date

CERTIFICATION

This dissertation entitled, "Impact of 5Es Problem-Solving Model on Science Process-Skills Acquisition, Performance and Retention in Cell Physiology among Secondary School Biology Students, Zaria, Nigeria", by Sadiq USMAN with registration number P16EDSC8074, meets the regulations governing the award of Master's Degree in Biology Education, Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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Prof. F.K. Lawal Date

Chairperson, Supervisory Committee

__________________________ _______________

Prof. M.M. Atadoga Date

Member, Supervisory Committee

__________________________ _______________

Prof. S.S. Bichi Date

Head of Department

__________________________ _______________

Prof. Sani Abdullahi Date

Dean, School of Postgraduate Studies.

DEDICATION

This dissertation is dedicated to my beloved parents, Chief Usman Asedu and Mrs Ramatu Usman; my siblings, Idris, Zakariyya, Faruk, Abdulmalik, Mubarak and Amina Usman; and my dear wife Maryam Ibrahim.

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LIST OF ABBREVIATIONS

AAAS	-	American Association for the Advancement of Science
ANCOVA	-	Analysis of Covariance
ANOVA	-	Analysis of Variance
BSCS	-	Biological Sciences Curriculum Study
BSPS	-	Basic Science Process-Skills
CHEM	-	Chemical Educational Materials
CPPT	-	Cell Physiology Performance Test
ISPS	-	Integrated Science Process Skills
NERDC	-	Nigerian Educational Research and Development Council
NISP	-	Nigerian Integrated Science Project
NSSSP	-	Nigerian Secondary Schools Science Project
PSCS	-	Physical Science Study
SAPA	-	Science – A Process Approach
SPSAT	-	Science Process-Skills Acquisition Test
UNESCO	-	United Nations Educational, Scientific and Cultural Organization
UNICEF	-	United Nations International Children’s Education Fund

OPERATIONAL DEFINITION OF TERMS

5Es Instructional Model: A constructivist, problem-solving and inquiry-based teaching approach that sequences learning experiences so that students have the opportunity to construct their understanding of a concept over time. It involves five phases of instruction namely, Engagement, Exploration, Explanation, Elaboration and Evaluation.

Conventional Method: The Lecture Method of teaching which places the teacher as a sole dispenser of knowledge and the students as passive recipients. The teacher does most of the talking while students listen with minimal participation.

Science Process-Skills: Cognitive and psychomotor skills employed in scientific investigations and problem solving which are acquirable or developed by students through training and practice.

Acquisition: The act or process of gaining, learning or developing the scienceprocess-skills by the expenditure of one's own physical and mental efforts.

Process-Skills Acquisition: The outcome of students' competency in utilizing their knowledge of or acquired science process-skills to solve problems.

Retention: The ability of a learner to store information after exposure to a series of instruction or training which can be recalled at a later time.

Academic Performance: The overall measure of the attainment of students in a given test after a period of instruction usually weighed as a score. It is the outcome of the test given to students by the researcher after administering treatment in Biology the aim of which is to determine the effect of the treatment given to the students.

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ABSTRACT

This study investigates the impact of 5Es Problem-Solving Model on science process-skills acquisition, performance and retention in Cell Physiology among Secondary School Biology Students in Zaria Education Zone, Kaduna State, Nigeria. The study adopts a Quasi-Experimental Design of Pretest-Posttest, Non-Equivalent Groups. The population comprised all 7,807 SS2 Biology students from 30 public Senior Secondary Schools in Zaria Education Zone. A sample of 110 students from two randomly selected co-educational schools was used for the study. The study involves two groups. The experimental group was taught Cell Physiology using 5Es Model while the Control Group was exposed to the same concept using Conventional Method. Two validated instruments were used for data collection, namely, Science Process Skills Acquisition Test (SPSAT) and Cell Physiology Performance Test (CPPT).These have reliability coefficients of 0.84 and 0.89 respectively,estimated using Pearson Product Moment Correlation (PPMC) statistic. Six research questions and six null hypotheses guided this study. Research questions were answered using Mean and Standard Deviation statistics while null hypotheses were tested using Independent Samples t-test at 0.05 level of significance.Findings reveal a significant difference between the mean scores of experimental and control groups in their science process-skills acquisition, performance and retention, all in favour of the experimental group. The results also show that male and female students in the experimental group do not significantly differ in the variables studied. Based on these findings, the researcher concludes that the 5EsModel is effective and gender-friendly infosteringthe examined variables among secondary school Biology students. It is therefore recommended that Biology teachers frequently employ this model in teaching challenging concepts in Biology like Cell Physiology.

CHAPTER ONE

THE PROBLEM

1.1 Introduction

Science and technical education are foundations for sustainable national development as they protect human societies from ignorance, illiteracy, disease and poverty. According to Omiko (2015), the use of science, technology and productivity are often to describe the level of development of a nation. In a statement by Okoli (2005), whatever plans that are made towards national development must include science education as an integral part of the school curriculum. In fact, Usman (2008) posits that people live in a world where science and technology have become integral parts of human culture and any country that overlooks this significant truism does so at the risk of remaining backward in an advancing world. Hence, Omiko (2015) concluded that no nation can make appreciable progress in terms of development without correct scientific base. Science has been defined by Pearson Education (2003) as knowledge about the world especially based on examining, testing and proving facts. According to Rao (2007), science is the system of knowing the universe through data collected by observation and controlled experimentation.

The National Policy on Education (FRN, 2013) sets as a goal for science education in Nigeria that government shall popularize the study of science and production of adequate number of scientists to inspire and support national development. Based on this policy, Omiko (2015) deduced that the aim of science and technology education is to inculcate science and technology in the thinking and working processes of the society in order to create science and technology culture. Science subjects offered in the Nigerian Senior Secondary Schools as recognised by the West African Examinations Council (WAEC) and the National Examinations Council (NECO) in their Chief Examiner's Reports include Biology, Chemistry, Physics, Physical Education, Agricultural Science and Health Education.

Biology is one of the science subjects that occupy a significant position in the senior secondary school curricula. Okenyi (2015) defined it as a branch of science that is structured to equip students with knowledge of life processes and phenomena of living organisms. Biology plays a vital role in providing knowledge of relevant concepts about living things and developing scientific skills and attitudes. Ibrahim (2015) further stated that Biology is a subject specially designed to provide students with skills and attitudes of caring about themselves, other organisms and the environment. In fact, Ghumdia (2017) stipulates that when the knowledge of Biology is acquired and applied in any society, it can bring about rapid and sustainable national development. To further emphasize its significance, Lawal (2010) stated categorically that a credit pass in Biology would determine to a large extent whether or not a candidate could be admitted to read a number of major professional science based courses at university such as Human and Veterinary Medicine, Pharmaceutical Sciences, Agricultural Science, Nursing Sciences, Biochemistry, Biotechnology, Bioinformatics, Forensic Sciences and to mention a few. This is perhaps why the Nigerian Educational Research and Development Council (NERDC, 2012) noted that the science subject is required for everyday life especially on matters of personal and community health and agriculture.

However, contrary to the stated objectives of science education in Nigeria and despite the importance of Biology as a science subject, empirical studies such as those of Etobro and Fabinu (2017) and Adegboye, Ganiyu and Isaac (2017) have shown that students still perform poorly in Biology at Senior Secondary School level. Lawal (2010) reported that Biology is one of the science subjects having downward trend in the performance of students at Senior School Certificate Examinations (SSCE). In fact, the failure rate in Biology is even more alarming compared to Chemistry and Physics despite its popularity among science students. In agreement to Lawal's position, Timothy (2013) noted that a review of students' enrolment in science subjects at senior secondary schools in Nigeria shows that more students register Biology than any other science subject but their academic performance in the subject is comparatively lower at SSCE.

In addition, the poor academic performance in SSCE Biology has become a trend in the WAEC results of Nigerian candidates from 2008 to 2017 as indicated in Table 1:

Table 1: Students' WASSCE Biology Results in Nigeria (2008 - 2017).

Year	Number of Candidates in Attendance	Number of Candidates that passed	Number of Candidates that Failed	%Passed (A1-C6)	%Failed (D7-F9)
2008	1,260,000	427,644	832,356	33.94	66.06
2009	1,340,489	383,112	957,377	28.58	71.42
2010	1,300,630	645,633	654,997	49.64	50.36
2011	1,505,409	579,432	925,977	38.49	61.51
2012	1,646,225	587,044	1,059,181	35.66	64.34
2013	1,698,187	564,138	1,134,049	33.22	66.78
2014	1,692,535	529,425	1,163,110	31.28	68.72
2015	1,701,048	508,613	1,192,435	29.90	70.10
2016	1,743,263	525,245	1,218,018	30.13	69.87
2017	1,798,052	521,255	1,276,797	28.99	71.01

Source: WAEC Office, Lagos (2017).

Table 1 shows that the total number of students that failed Biology over the years under review has relatively remained on the increase as the total enrolment increases. Similarly, 66.02% of candidates on the average could not pass Biology at Credit level to meet the minimum requirements for admission into science related courses at higher institutions.

Furthermore, the poor performance in SSCE Biology becomes more evident from the reportsof WAEC for Kaduna State candidates from 2009 to 2017 as shown in Table 2:

Table 2: Students' WASSCE Biology Results in Kaduna State (2011 - 2017).

Year	No. Released	No. Passed	% Pass	No. Failed	% Fail
2011	26,734	2,877	10.76	23,857	89.23
2012	28,496	4,957	17.40	23,539	82.60
2013	33,614	3,274	9.74	30,340	90.26
2014	21,315	3,156	14.81	18,159	85.19
2015	25,798	4,873	18.89	20,925	81.11
2016	28,500	4,993	17.52	23,507	82.48
2017	30,614	5,734	18.73	24,880	81.27

Source: Statistics Section, WAEC Office, Lagos, Nigeria (2017).

Table 2 reveals that Biology has a high number of enrolments among candidates in Kaduna State yet it records a massive failure rate averaged at 84.59% over the seven years under review. This is alarming! A disheartening 90.26% failure was recorded in 2013 which represents the highest reported in Kaduna State while the lowest recorded is 81.11% in 2015.

This high failure rate at SSCE Biology according to Lawal (2010) and Timothy (2013) has continued to be a source of worry to curriculum planners, educationists, parents, and the entire society. Reports from several studies like Omorogbe and Ewansiha (2013), Okenyi (2015) and Etobro and Fabinu (2017) have indicated that a vast number of factors are responsible for this poor performance. Prominent among these factors include the difficult and abstract nature of a number of Biology concepts like Genetics, Evolution, Ecology and Cell Physiology, inadequacy and poor use of instructional materials, teachers' prevalent use of traditional teaching methods, lack of practical classes to foster acquisition of science process-skills and poor attitude of teachers towards teaching for better retention, among others. All these have contributed directly or indirectly to the dilapidation in quality of Biology teaching and learning in Nigeria especially in regards to the acquisition of Science Process-Skills which are invaluable in the 21st century.

Science Process-Skills, according to Njoku (2002), are cognitive and psychomotor skills employed in scientific investigation and problem solving. In another definition, Cyril (2012) sees science process-skills as skills which scientists employ in their investigations and which can be acquired or developed by students through training such as are involved in science practical activities. According to Karamustafaoglu (2011), the Science Process skills are broadly grouped into two; namely: Basic and Integrated Science Process Skills. The Basic Science Process Skills (BSPS)include observing, classifying, measuring, communicating, inferring and predicting while the Integrated Science Process Skills (ISPS) includeidentifying and defining variables, collecting and transforming data, constructing tables ofdata and graphs, describing relationships between variables, interpreting data, manipulatingmaterials, recording data, formulating hypotheses, designing investigations, drawingconclusions and generalizing. It is therefore not surprising as Nwagbo and Chukelu (2011) stated that the acquisition and use of these skills by students is one central purpose of science education in Nigeria. Aktamis and Ergin (2008) also noted that these skills enable students to define problems around them, observe, hypothesize, experiment, analyze, conclude, generalize and apply the information they derive to solve problems.

Despite the numerous benefits of science process-skills in the teaching and learning of science especially Biology, Omiko (2015) observed that many Nigerian students do not demonstrate proficiency in their acquisition. In fact, WAEC (2014) has linked candidates' poor performance in Biology to their poor mastery of the practical aspects of Biology which stemmed from their poor acquisition and use of the science process-skills. Nweke (2015) is of the same opinion having observed that poor performance in practical work is tantamount to poor acquisition of science process-skills. Hence, to help improve students' acquisition of science process skills and academic performance in Biology, innovative strategies which provide students with hands-on learning experiences need to be employed to teach the subject effectively. Biology teachers need to employ methods that will enable students to learn better, retain more knowledge and apply what is learnt to real life situations. This is why Ibrahim (2015) suggested that the 5Es Problem-Solving Model may offer a promising opportunity in this respect.

The 5Es Instructional Model is defined by Duran and Duran (2004) as a constructivist, problem-solving and inquiry-based model that uses five phases of instruction namely; Engagement, Exploration, Explanation, Elaboration and Evaluation. In literature, it is interchangeably called the BSCS 5Es, Constructivist 5Es Model, 5Es Teaching Cycle Model, 5Es Teaching Cycle, 5Es Learning Cycle Model, 5Es Learning Model, 5Es Learning Cycle or simply the 5Es Model. According to O' Brein (2013), the 5Es Teaching Cycle is an instructional model for designing series of experimentally rich lessons that are conceptually linked and developmentally sequenced to support the on-going, progressive refinement in student understanding as it develops over time. Senan (2013) explains that the 5Es Instructional Model was developed in the 1980s by a non-profit organization named Biological Sciences Curriculum Study (BSCS) under the leadership of Rodger Bybee. Unlike the traditional expository methods like Lecture, which places the teacher as a sole dispenser of knowledge and the students as passive listeners, the 5Es model aims to have students derive concepts and principles experimentally from scientific investigations. As a result, Boddy, Watson and Aubusson (2003) emphasized that students not only acquire content knowledge, but also retain more as well as develop scientific attitudes, science process-skills and cognitive skills such as critical reasoning and problem solving.

According to Balta and Sarac (2016), several models of the Constructivist Instructional Approach or Learning Cycles appear in literature ranging from '3E' which was developed by Karplus and Their (1967), '5E' by Bybee (1997), '7E' by Eisenkraft (2003) and '9E' by Kaur and Gakhar (2014). Studies like Anil and Batdi (2015) and Balta and Sarac (2016) have shown that the use of these models in science teaching furnish content of the courses, increase students' attention towards courses, ensure permanent learning, change students' prejudgements towards science and make courses more entertaining and fruitful. The 5Es Model according to Cakir (2017) has the advantage over others for being concise and time-effective during implementation. In essence, it could possibly be more effective in the teaching and learning of difficult and abstract Biology concepts like Cell Physiology.

Cell Physiology is one of the major concepts in SSCE Biology Curriculum. It is described by Lawrence (2008) as a biological study of the activities that take place in a cell to keep it alive which include taking in nutrients, expelling wastes and reproducing. The topics under Cell Physiology in the Nigerian Senior Secondary Biology Curriculum by NERDC (2012) are captured under two broad areas - 'The Cell and its Environment' and 'Some Properties and Functions of the Cell'. Several research reports like those of Agboghoroma and Oyovwi (2015), Chatila and Al-Husseiny (2017) and Etobro and Fabinu (2017) as well as WAEC Chief Examiner's Reports (2009-2015) agree on the difficulty of the topics under Cell Physiology among students at the Senior Secondary Schools. This difficulty is evidenced by the recurrent failure recorded by candidates in questions associated with the concept in external Biology examinations like WASSCE and NECO. Therefore, the 5Es Instructional Model is to be employed in this study perhaps as a possible means of remediating this difficulty and enhancing secondary school students' retention of this concept.

Retention has been defined by Jiya (2011) as the ability of a learner to store information which can be recalled at a later time after exposure to a series of instruction or training. According to Olanrewaju (2012), it is the ability to store learned concepts which can easily be recalled from the short and long-term memory. Wada (2016) stated that the appropriate coding of information provides the consulted index for retention to take place without an elaborate search in the memory lane. Hence, strong retention of learnt concepts symbolizes concretized learning and engenders knowledge applicationfor problem solving. Among the factors capable of aiding students' retention as outlined by Ibrahim (2015) is the instructional strategy adopted in teaching the concept. Researches such as Ergin (2006), Bunkure (2012), Ibrahim (2015) and Anil and Batdi (2015) have shown that retention of scientific concepts is better enhanced by exposure to 5Es Instructional Model than Traditional Lecture Method. The reason for this is as stated by Boddy, Watson and Aubusson (2003) that the 5Es Learning Cycle Model facilitates better processing of information, leading to deeper understanding and better retention of learnt concepts.

Another variable that has been of concern to researchers in science education is gender. According to Lewis (2011), it is the property that distinguishes individuals based on their reproductive roles. Research conducted on the effects of gender on students' acquisition of science process-skills and academic performance has so far been inconclusive. Studies by Eng, Puspa, Kenneth, Nick and Siti (2015), Ugwanyi (2015) and Rabacal (2016) indicate that gender has no significant effect on students' acquisition and mastery of science process-skills. On the contrary, Ong, Wong, Sopia, Sadia, Asmayati and Zahd, (2012), Zeidan and Jayosi (2015) and Ongowo (2017) indicated that significant differences exist among male and female students in their acquisition of science process-skills. Likewise, researches on gender and academic performance such as those of Ibrahim (2012) and Umar (2013) reveal that boys achieved academically better than girls. On the other hand, studies by Bunkure (2012) and Dahiru (2013) pointed out that female students achieved academically better than their male counterparts. However, a number of other studies like Ibrahim (2015) and Umahaba (2016) reveal no significant difference in the academic performance of male and female students. Therefore, this study among other things is set to find out if gender will have any effect on students' learning outcomes as regards their science process-skills acquisition, performance and retention in Biology.

In conclusion, a number of studies like Balci (2006), Ndioho (2007), Ozlem and Jale (2010) and Ibrahim (2015) have been carried out using 5Es Instructional Model in Biology but aspects of relating 5Es to science process-skills acquisition, retention as well as the teaching and learning of Cell Physiology concept is limited. Therefore, the researcher seeks to investigate the impact of 5Es Problem-Solving Model on science process-skills acquisition, academic performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone, Kaduna State, Nigeria.

1.1.1 Theoretical Framework

This study is hinged on two theoretical frameworks. The first is the Theory of Cognitive Constructivism proposed by Piaget (1970) and the second is the Theory of Social Constructivism by Vygotsky (1978). The Theory of Cognitive Constructivism postulates that learners have the ability to build their own understanding of new ideas by drawing on their prior knowledge, beliefs and skills and synthesizing those with the new information (Corporation for Public Broadcasting (CPB), 2002;

Erickson &Verstynen, 2017). According to Piaget (1970), individuals must construct their own knowledge through experience - interaction with objects and events - that leads to the creation of schemas or mental modes that facilitate learning. The 5Es Instructional Model is aconstructivist strategythat presents learning in a series of steps beginning with the engagement of students' previous knowledge or past experiences, through the exploration of relevant materials and aspects of the environment in search for meaningful explanations to concept and phenomena, to the application of knowledge gained in real life situations for problem solving. Throughout the teaching-learning process with the 5Es Model, students are mentally and physically engaged as they not only manipulate instructional materials in experimental conditions but also engage in critical and reflective thinking while searching for the most plausible explanations to scientific phenomena or seeking viable answers to thought-provoking questions put forward by the teacher to guide their inquiry. In this context, the 5Es learning cycle offers students the opportunity to acquire and master the science process-skills as well as develop their cognitive and psychomotor abilities as they work in an environment that encourages intellectual soundness and manual dexterity. Students also get to improve their retention ability due to the depth of processing learnt information are subjected to.

The Theory of Social Constructivism on the other hand postulates that peers and adults greatly influence learning and the acquisition of science concepts (CPB, 2002; Erickson &Verstynen, 2017). Vygotsky (1978) argued that individuals can, with the help of a more experienced peer, master concepts and ideas that they otherwise cannot understand on their own. The 5Es Instructional Model presents learning in a social context. In the 5Es lesson, every student engages with other students in constructing new ideas based on previous experiences, carrying out activities or experiments, seeking explanations to scientific phenomena, thinking out solutions to problems as well as finding possible applications of learnt concepts to real life situations under the guidance of the teacher. Here, the teacher organizes the students into small interactive groups and facilitates a productive learning experience within and amongst them. Each student in the 5Es classroom is able to learn from his/her personal experience and those of his peers as well as from the expertise of his/her teacher. In this context therefore, students get the opportunity of developing the skills of communication and prediction as well as their affective domain as they learn in an environment that encourages social interaction. Such positive interdependence also leads to memories that sustain retention of learnt concepts.

Based on these tenets therefore, the present study adopts the 5Es Problem-Solving Model in teaching Cell Physiology concepts to examine its effects on science process-skills acquisition, academic performance and knowledge retention among secondary school Biology students in Zaria Education Zone, Kaduna State, Nigeria.

1.2 Statement of the Problem

The main objective of teaching Biology at Senior Secondary Schools is to impart meaningful and relevant knowledge as well as inculcate in the learners, adequate laboratory and field skills. This substantiates the need for the development and mastery of science process-skills by Biology students in Senior Secondary Schools. Since the basic science process-skills as described by Ongowo (2017) are foundational tools for construction of new knowledge, it follows that a proper acquisition and mastery of these skills could engender meaningful learning, enhanced academic performance and better retention of learnt concepts. However, studies of Nwagbo and Chukelu (2011), Ajayi and Osoko(2013), Omiko (2015) and Ghumdia (2016) which were conducted among students in Nigeria have shown that the acquisition and mastery of science process-skills have been poor over the years. WAEC (2014) has also adduced the poor acquisition of science process-skills among SSCE Practical Biology candidates due to their poor performance in the aspects of drawing, labelling, spelling, conforming to specifications, making essential observations, reporting findings, describing experiments, drawing conclusions as well as plotting and interpretation graphs. Although a handful of empirical studies like that of Biyikli (2013), Acisli (2014), Ozturk, Geren and Dokme (2015) and Cakir (2017) have indicated the efficacy of 5Es Instructional Model in enhancing the acquisition of science process-skills among students, most of them are conducted outside Nigeria. Local literatures in this subject seem to be very limited. Therefore, this study aims to investigate the impact of 5Es Instructional Model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone, Kaduna State, Nigeria.

Gender differences in cognitive abilities have also been widely analyzed in the psychological and neuropsychological literature. Ardila, Roselli, Matute and Inozemtseva(2011) and Abraham (2015) reported three major differences in cognitive abilities between males and females. These differences include higher verbal abilities favouringfemales,higher spatial abilities favouringmales and higher arithmetical abilities also favouringmales. However, much of the empirical evidence like those presented by Flynn and Rosi-Case (2011) and Abraham (2015) have confirmed that boys and girls are not different in terms of general intelligence. The explanations that have been advanced by Abraham (2015) and Vuoksimaa(2004) to justify the apparent gap between the sexes in their cognitive abilities and achievement include both biological and socio-cultural factors. The most common biological factors include genetic differences, hormonal differences and brain differences in overall size, variability and organization. The socio-cultural factors widely discussed include societal constraints, cultural factors and socialization differences. These gender-dependent factors may perhaps also have influence on other cognitive abilities like acquisition of science process-skills, academic performance and knowledge retention. The thrust of this study therefore, is to examine whether gender will have any effect on secondary school Biology students' acquisition of science process skills, academic performance and retention when exposed to the 5Es Instructional Model.

1.3 Objectives of the Study

The objectives of this study are to:

i. examine the impact of 5Es Instructional Model on the acquisition of science process-skills in Cell Physiology among secondary school Biology students;

ii. investigate the impact of 5Es Instructional Model on the acquisition of science process-skills in Cell Physiology among male and female secondary school Biology students;

iii. determine the impact of 5Es Instructional Model on the academic performance of secondary school Biology students in Cell Physiology;

iv. examine the impact of 5Es Instructional Model on the academic performance of male and female secondary school Biology students in Cell Physiology;

v. investigate the impact of 5Es Instructional Model on the retention ability of secondary school Biology students in Cell Physiology; and

vi. determine the impact of 5Es Instructional Model on the retention ability of male and female secondary school Biology students in Cell Physiology.

1.4 Research Questions

The following research questions are formulated for answering:

i. What is the difference between the mean science process-skills acquisition scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method?

ii. What is the difference between the mean science process-skills acquisition scores of male and female secondary school Biology students taught Cell Physiology using 5Es Instructional Model?

iii. What is the difference between the mean academic performance scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method?

iv. What is the difference between the mean academic performance scores of male and female secondaryschoolBiology students taught Cell Physiology using 5Es Instructional Model?

v. What is the difference between the mean retention scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method?

vi. What is the difference between the mean retention scores of male and female secondaryschoolBiology students taught Cell Physiology using 5Es Instructional Model?

1.5 Null Hypotheses

Based on the objectives and research questions stated, the following null hypotheses are formulated for testing at P ≤ 0.05 level of significance:

HO_1: There is no significant difference between the mean science process-skills acquisition scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method.

HO_2: There is no significant difference between the mean science process-skills acquisition scores of male and female secondary school Biology students taught Cell Physiology using 5Es Instructional Model.

HO_3: There is no significant difference between the mean academic performance scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method.

HO_4: There is no significant difference between the mean academic performance scores of male and female secondaryschoolBiology students taught Cell Physiology using 5Es Instructional Model.

HO_5: There is no significant difference between the mean retention scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method.

HO_6: There is no significant difference between the mean retention scores of male and female secondaryschoolBiology students taught Cell Physiology using 5Es Instructional Model.

1.6 Significance of the Study

The findings of this study will hopefully uplift the standard of Biology education in the following ways:

- **Biology Teachers:**It is hoped that the findings from this study would benefit Biology teachers in equipping them with how to and enlightening them on the need to teachstudents difficult concepts in Biologylike Cell Physiology using the 5Es Instructional Model.
- **BiologyStudents:** This study would equip Biology students with effective inquiry, social interaction, creative thinking, problem solving and science process skills; help them develop a positive attitude towards learning concepts perceived as difficult in Biology like Cell Physiology as well as may probably enhance their academic achievement and retention ability in these concepts.
- **Higher Institutions:**It would benefit institutions of higher learning such as Colleges of Education and Universities where Biology teachers are trained by making resources on 5Es Instructional Model available for the lecturers to adequately train the prospective teachers who will in turn apply this knowledge in helping their students at the secondary and basic education levels.
- **Professional Bodies:**It would be useful to professional bodies like the Science Teachers Association of Nigeria (STAN) who are involved in and concerned with the outcomes of research especially those on instructional innovations to emphasize and encourage further

studies in the 5Es Instructional Model in order to fully unveil its potentials.

- **Curriculum Planners:** It would be of great benefit to curriculum developers such as the NERDC by bringing into focus the effectiveness of the 5Es Instructional Model, thereby enabling them to make necessary amendments to the curriculum where necessary.
- **Textbook Publishers:** Textbook publishers will also incorporate materials on the 5Es Instructional Model so as to ease comprehension of textual materials by students and advance the frontiers of knowledge therewith.
- **Researchers:** This study will also help researchers by contributing to literature on the 5Es Instructional Model and stimulating further research from which new findings would be made that would collectively result in uplifting Science Education in general and in particular, Biology education in Nigeria.

1.7 Scope of the Study

This study is designed to investigate the impact of 5Es Problem-Solving Model on science process-skills acquisition, academic performance and retention in Cell Physiology. Public Senior Secondary School II (SS2) Biology students in Zaria Education Zone, Kaduna State, Nigeria participated in this study. The schools are owned by the Government and the same Ministry of Education supervises teaching and learning activities in them. The SS2 students are considered suitable for this study because they are stable and have experience in basic Biology concepts from their previous class (SS1). This is unlike SS1 students who are neither experienced in Biology nor fully settled for the study due to enrolment issues or SS3 students who are faced with their SSCE examinations.

The method of instruction employed in this study is the 5Es Problem-Solving Model adopted from Bybee, et al (2006). The Cell Physiology concept is chosen for this study because topics therein are difficult for secondary school Biology students to understand and pass as evidenced by the research findings of Cimer (2012), Agboghoroma and Oyovwi (2015), Chatila and Al-Husseiny (2017), Etobro and Fabinu (2017) and WAEC (2009-2017). The topics chosen under Cell Physiology include:

1. Diffusion and its application in living and non-living systems;
2. Osmosis and its application in living and non-living systems;
3. Active Transport, Endocytosis and Exocytosis and their applications;
4. Cellular Respiration (Catabolism);
5. Photosynthesis (Anabolism);
6. Mitosis and Meiosis and their applications.

Science process-skills considered in this study are the Basic Science Process Skills (BSPS) which include observation, communication, classification, measurement, inference and prediction. The BSPS are considered appropriate for this study because, as indicated by Karamustafaoglu (2011) and Ongowo (2017), they form the foundation for the scientific method, are tools for the construction of new knowledge, are operationally less difficult, intellectually less demanding and can be combined with content learning in a seamless experience.

1.8 Basic Assumptions

The study has the following basic assumptions:

i. The schools for this study have facilities for effective teaching and learning of Biology using 5Es Problem-Solving Model.
ii. The sampled schools for this study use the same Biology curriculum, Syllabus, Scheme of work and recommended textbooks.
iii. The Biology teachers in the schools are qualified and as such can teach Biology effectively.
iv. The methods of instruction used in teaching Biology in secondary schools usually do not include all stages of the 5Es Problem-Solving Model.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction

This study seeks to investigate the Impact of 5Es Problem-Solving Model on Science Process-Skills Acquisition, Academic Performance and Retention in Cell Physiology among Secondary School Biology Students in Zaria Education Zone, Kaduna State, Nigeria. This chapter reviews relevant and related literature on the topic of the research and are presented under the following sub-headings:

2.2 Historical Perspective of Science Education in Nigeria;

2.2.1 Philosophy and Objectives of Science Education;

2.2.2 Philosophy and Objectives of Biology Education;

2.3 Problems of Teaching and Learning Biology in Nigerian Senior Secondary Schools;

2.3.1 Students' Academic Performance in Biology at Senior Secondary Schools;

2.3.2 Trends of Senior Secondary School Students' Performance in Cell Physiology Concepts;

2.4 Science Process-Skills Acquisition among Senior Secondary School Students;

2.4.1 Relevance of Science Process-Skills to Science Education;

2.5 Instructional Strategies in the Teaching and Learning of Biology;

2.5.1 The Concept of 5Es Instructional Model;

2.5.2 5Es Instructional Model and Academic Performance in Biology;

2.5.3 5Es Instructional Model and Process-Skills Acquisition;

2.5.4 5Es Instructional Model and Retention Ability of Senior Secondary School Students;

2.6 Gender and Academic Performance in Biology;

2.6.1 Gender and Science Process-Skills Acquisition;

2.6.2 Gender and Retention Ability of Students in Biology;

2.7 Overview of Similar Studies;

2.8 Implications of the Literature Reviewed for the Present Study.

2.2 Historical Perspective of Science Education in Nigeria

The origin of science and science education according to Omiko (2015) and Ibrahim (2015) could be as old as the human race itself, arising from the need of man to solve various problems that threatened his survival as well as his desire to transmit the knowledge, ideals, values and norms acquired thereof to the younger generation. Ogunmade (2005) notes, before the advent of Western education in Nigeria, certain aspects of scientific knowledge were included in traditional forms of education. The arrival of the British missionaries on the coast of Lagos in 1859 and subsequent establishment of churches and elementary schools in the town of Topo near Badagry in 1861 marked the beginning of western education in Nigeria. As stated in Martins Library BlogSpot (MLB) (2013), the establishment of Church Missionary Society (CMS) Grammar School in Lagos in 1859, Roman Catholic Missionary (RCM), Wesleyan Methodist Mission (WMM), African Mission of South Baptist Convention, United Presbyterian Mission of Scotland Mission, the Qua Ibo Mission, introduced some rudiments of science education into the schools' curriculum including arithmetic, algebra, geometry and physiology. Missionaries also established other schools namely, grammar, teacher training, pastoral, vocational and agricultural schools and the introduction of rudiments of science in school curricula and teaching of them. The curriculum consist of 4Rs namely, reading, writing, arithmetic and religion. The Hope Waddell Institute in Calabar founded in 1861, St.

Andrews College, Oyo in 1876, Wesleyan Training Institute of 1905, Baptist Training Centre, Ogbomoso of 1899, etc. had science subjects in their curricula.

In the account of Jimoh, Maigamo and Abari (2010), Science was first introduced as Nature Study in Nigeria by British Missionaries with the establishment of the Church Missionary Society (CMS) Grammar School, Lagos in 1859. This rudiment of science involved the teacher and his pupils learning about the environment in a form of outdoor observation of plants, animals and non-living things. However, Ojebiyi and Fasakin (2014) added that by 1920, the zeal for Nature Study began to decline and it was no longer consistent with the psychology, philosophy and methodology of the time. Nature Study was no longer adequate for the social and economic realities of the period, thus, making the change imminent. The change was felt in Nigeria with the introduction of General Science in the secondary school. Later, Brown (2015) noted that the three main branches of science - Biology, Chemistry and Physics - were introduced for the last three years of secondary education in the 1950s.

Furthermore, Ojimba (2013) noted that science education has undergone several curricular reforms to connote the science development efforts which were sparked off during the 1960s and 1970s by the sudden launching into space of the satellite "Sputnik" by the defunct Soviet

Union in 1957. The development created the curiosity and subsequent questioning of the mode of science teaching and learning and the nature of the science curriculum existing in the United States of America and other nations of the world. Subsequently, several new science curricula evolved which include the Physical Science Study (PSCS), Chemical Educational Materials Study (CHEM study), Biological Science Curriculum Study (BSCS), all in the United States, and the Nuffield Science Projects in the United Kingdom.

Brown (2015) added that, the Nigerian nation became a part of these curriculum development efforts with the birth of Basic Science for Nigerian Secondary Schools (BSNSS) undertaken by the Comparative Education Study and Adaptation Centre (CESAC) and the Science Teachers Association of Nigeria (STAN) in 1962 at the Comprehensive High School, Aiyetoro. The historic National Curriculum Conference that held from 8th to 12th September, 1969 further spurred various bodies including government agencies to fully participate in many other science curriculum development projects both at the primary and secondary levels of our educational system, which brought about the new National Policy on Education (NPE) of 1977 revised in 1981 wherein the 6-3-3-4 system of education was ushered with the following:

i. The Nigerian Secondary Schools Project (NSSP) by the defunct CESAC;

ii. The Nigerian Integrated Science Project (NISP) in 1971 by STAN;
iii. The Primary Education Improvement Project: Northern States Primary School Project (NSPSP) by the Institute of Education, Ahmadu Bello University (ABU), Zaria;
iv. Science is Discovering: Mid-Western State Primary Science Project (MSPSP) by Abraka College of Education;
v. The Primary Education Improvement Project: Western States Primary Science Project (WSPSP) by the Faculty of Education, Obafemi Awolowo University (OAU), Ile-Ife; and
vi. The Lagos State Primary Science Project (LSPSP) by the Lagos State Ministry of Education.

However, Ojimba (2013) emphasized that the bottom-line of these curricular reform efforts hinged on the fact that there was total dissatisfaction with how science was still traditionally being taught. The traditional approach resulted to the decreasing popularity of science among students as evidenced by the declining number of students choosing science subjects.

The introduction of Higher School Certificate (HSC) in 1951 as noted in MLB (2013), gave schools the opportunity to offer Chemistry, Biology and Physics at higher level, with emphasis on Laboratory work to meet the practical requirements of science subjects. In 1952, an examination board was set up with its headquarters in Accra, Ghana following the

Jeffery's Report of 1950. The board later became the West African Examinations Council (WAEC), which reviewed the curriculum of school subjects including science, with its first examination in 1995. STAN, which was established on 30th November, 1957, revised the science curriculum of WAEC and HSC in May, 1968. Ado (2012) noted specifically that WAEC in 1968 reviewed its syllabus in Biology, Chemistry and Physics calling on the assistance of STAN.

Ojebiyi and Fasakin (2014) related that up to 1932, there was no post-secondary institution for the learning of science after the only specialized institution, the medical school attached to the CMS Theological Institute founded in Abeokuta in 1961, folded up. The teaching of science however gained a better footing in about 1920 because of the recommendation of an African Education Commission which toured the British West African colonies under the sponsorship of the Phelps Stokes Fund of America. The establishment of Yaba College in 1932, later upgraded to Yaba College of Technology in 1963, to run courses in engineering, medicine, science agriculture, survey and teacher training was meant to fill vacancies in relevant government developments as noted by Brown (2015). The college also produced the first set of graduates who taught science in secondary schools and played major role in laying the foundation for the development of appropriate curriculum for science in the secondary schools. Another giant stride in the development post-secondary school science education is the establishment of the University College, Ibadan in 1948 as College University of London following the report of the Elliot Commission for Higher Education set up in 1943 which reloaded the establishment of a university in Nigeria. The University College remained with status of the University of London up to 1960 when it started awarding its own degree and became University of Ibadan in 1962. In addition, the Federal Colleges of Arts, Science and Technology at Ibadan in 1950, Zaria in 1952 and Enugu in 1954 administered a fairly comprehensive curriculum in science education and science related fields e.g. Architecture, Engineering, Pharmacy, etc. These colleges later became OAU in 1962, ABU 1962 and UNN in 1960 respectively.

It is evident from the reviewed historical background that science education in Nigeria has evolved from the age-long desire of the Nigerian communities to transmit relevant knowledge, skills values and norms to their younger generation through traditional and informal forms of education like mentorship and apprenticeship to the advent of Western or Formal Education which introduced the Nature Study. Nature Study was an elementary and rudimentary form of science education that later metamorphosed into General Science taught at the secondary school level. Today, General Science has become the three main branches of science (i.e. Biology, Chemistry and Physics) taught at Senior Secondary

Schools. More so, many science, advanced science and science-related disciplines are being offered in almost all Nigerian tertiary institutions to produce the manpower needed by the nation as well as to help the nation keep pace with the global advancement in science and technology.

Furthermore, it can be deduced from the reviewed historical background that there has been a significant transformation in the mode of science instruction in Nigeria that accompanied the various curricular reform projects that took place. This ranges from instruction by mere observation of living and non-living things which characterized Nature Study, through the teacher-centered "chalk-and-talk" mode of instruction characteristic of General Science to the more child-centered, inquiry and activity-based instructional models supported by the later science curricular projects. Prominent among these curricular projects include the Mid-West Primary Science Project (MPSP), UNESCO/UNICEF Primary Science Project, Ife Six Years Project (ISYP), Nigerian Integrated Science Project (NISP) and the Nigerian Secondary School Science Project (NSSSP). Curricular reforms initiated outside Nigeria that were also of immense benefit to the country include Biological Sciences Curriculum Study (BSCS), Chemical Education Materials (CHEM) Study, Science - A Process Approach (SAPA), Science and Improvement Study (SCIS), Conceptually Oriented Programme in Science

(COPES), Elementary Science Study (ESS) and Intermediate Science Curriculum Study (ISCS).

This research work is therefore seeks to examine the impact of the BSCS 5Es Problem-Solving Model on Science Process Skills Acquisition, Retention and Academic Performance in Cell Physiology among Secondary School Biology Students in Zaria Education Zone of Kaduna State, Nigeria.

2.2.1 Philosophy and Objectives of Science Education

Science education is globally receiving attention by governments having realized its relevance in the development of any nation. According to Ibrahim (2012), science education as a subject may simply be viewed as education for the development and acquisition of scientific knowledge and literacy. This is in order for the members of the society to be able to explain scientific phenomena for the promotion of a very sound technological and economic breakthrough as well as the upkeep of a steady manpower output. Ogunmade (2005) sees science education as a field of study concerned with producing a scientifically literate society and laying the foundation for future work in science and science related fields by acquainting the students with certain basic knowledge, skills and attitudes. The Federal Government of Nigeria via the National Policy on Education (FRN, 2013) has outlined a number of objectives for secondary education and therefore whatever is taught in secondary school science must be directed towards realizing the broad national objectives for secondary education. These objectives include the fact that secondary school education should:

i. provide an increasing number of primary school pupils with the opportunities for education of higher quality irrespective of sex or social, religious and ethnic background;
ii. diversify the secondary school curriculum to cater for the differences in talent, opportunities and roles possessed by or open to students after their secondary school courses;
iii. equip students to live effectively in the modern age of science and technology; and
iv. raise a generation of people who can think for themselves, respect the views and feelings of others, respect the dignity of labour and appreciate these values specified under that broad national aims of education and live as good citizens.

According to Bell, Blair, Crawford and Lederman (2003) an adequate understanding of the nature of science and scientific inquiry is the main instructional purpose of science education. Ogunmade (2005) however noted that the purpose and goals of science education include to:

i. develop creativity in learners;

ii. improve scientific and technological literacy of citizens;

iii. prepare citizens for an active contribution towards their own culture; and

iv. inculcate the spirit of scientific thinking in learners.

According to Ogunmade (2005), the American Association for the Advancement of Science (AAAS) had in 1989 argued that an understanding of science concepts and principles is crucial to developing scientific literacy and also for meaningful and productive careers in science and thus asserting that more and more jobs today require people who have the ability to learn, reason, think, make decisions and solve problems as well as engage in scientific discourse. Ojimba (2013) added that the AAAS in 1985 and 1993 had established a curriculum reform project code-named "Project 2061" and the conceptual basis for the reform has some basic features with the following aims:

i. To achieve scientific literacy as the central goal of science education focusing on students' understanding of the nature of science and by the study of its history and philosophy.

ii. To relate an understanding of major concepts, principles and habits of thinking in science, mathematics and technology to events or activities in the society.

iii. To achieve science standard for all students including girls, language, ethnic minorities and all ability groups in an attempt to encourage all students to succeed and to embrace excellence and equity.

iv. Te design science education to reflect that science is an active process, so that both hands-on as well as minds-on activities should constitute the core of the education process by teaching less content with greater depth of understanding.

v. To focus on inquiry as a central element of the curriculum to promote students to actively develop their understanding of scientific concepts, along with reasoning and thinking skills, through group based approaches and greater cooperation among science teachers and students while deemphasizing competition in the classrooms.

vi. To explore the use of alternative assessment techniques to paper and pencil test.

The AAAS' assertion concurs with the goals for science education enumerated in the report of the National Research Council (NRC) (1996) that the knowledge of science concepts and principles would help students to be able to:

i. experience the richness and excitement of knowing about and understanding the natural world;

ii. use appropriate scientific processes and principles in making personal decisions;

iii. engage intelligently in public discourse and debate about matters of scientific and technological concern; and
iv. increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers.

The NRC (1996) summed it all up by saying that scientifically literate persons are those who can think, ask questions, and provide logical and coherent answers to any situations and everyday experiences. Likewise, Craven & Penick (2001) noted that a scientifically literate student develops higher order cognitive thinking to identify and evaluate ill-defined problems, to make informed decisions, and also to provide a variety of solutions to any particular problem. Therefore, Ogunmade (2005) summed it up that understanding the nature of science and scientific inquiry to foster learners' ability to develop scientific literacy is the purpose and goal for science education.

2.2.2 Philosophy and Objectives of Biology Education

According to the National Council for Curriculum and Assessment (NCCA) (2001), the general aim of education is to contribute towards the development of all aspects of the individual, including aesthetics, creative, critical, cultural, emotional, expressive and intellectual, for personal and hope life, working life, living in the community and leisure. Science education in the senior secondary schools as observed by Dan-Ologe and Shittu (2008) should therefore reflect the changing needs of the students and the growing significance of science for strategic development of our country, with particular emphasis on the preparation of students for the requirements of further education or training for employment and for their role as participative enterprising citizens. In Nigeria, the National Policy on Education (2004, revised in 2013) provides that Mathematics and at least one of Biology, Chemistry, Physics or Health Sciences are to be offered as core subjects by students at the Senior Secondary School level. In line with this policy therefore, Dan-Ologe and Shittu (2008) stated with emphasis that as a science subject offered in all Nigerian senior secondary schools, the Biology curriculum should enable learners acquire the following:

i. Meaningful and relevant knowledge in the subject;
ii. Reasonable and functional scientific attitude;
iii. Adequate laboratory and field skills in the subject; as well as; and
iv. Ability to apply scientific knowledge to everyday life.

Hether (2007) noted that the study of Biology can have a multitude of aims and objectives but largely, it is studied to allow the learner to enter a specific field of employment like Human and Veterinary Medicine, Nursing Sciences, Pharmaceutical Sciences, Biochemistry, Biotechnology and Biology Teaching, among others. Other aims for studying Biology are intellectual, ethical and pragmatic: to increase knowledge about all types of organisms, to encourage greater benevolence in the relationship between humans and the natural environment and to implement biological skills into various technologies or management techniques. In a broader perspective, Okenyi (2015) stated that the major objectives of Biology education in Nigeria as a minimum standard for NCE teachers are to:

i. provide the youth with sound knowledge of the basic principles and techniques of Biology;
ii. produce knowledgeable, highly motivated, professional and effective teachers of Biology who will be able to develop in students an appreciation and understanding of biological processes and principles;
iii. develop confidence in Biology teachers and enhance the ability to adopt to the changing situation in science and the technological oriented society;
iv. view Biology as a process of inquiry into the living world;
v. analyze the activities of living things in their environment;
vi. demonstrate practical skills in handling scientific apparatus;
vii. demonstrate excellence and professional competence in teaching secondary school Biology;

viii. include positive scientific attitudes and value in the society and promote positive disposition towards Biology, science and the scientific enterprise; and

ix. apply concepts and methods acquired in new areas of study and in everyday situation.

However, the main objectives of the Senior Secondary School Biology Curriculum according to the Nigerian Educational Research and Development Council (2009) as derived from the National Policy on Education (2004, revised in 2013) are to prepare students to acquire:

i. adequate laboratory and field skills;

ii. meaningful and relevant knowledge in Biology;

iii. ability to apply scientific knowledge to everyday life in matters of personal and community health and agriculture; and

iv. reasonable and functional scientific attitude.

Finally, in pursuance of the stated objectives, the NERDC (2009) stated emphatically that the contents and context of the curriculum would place emphasis on field studies, guided discovery, laboratory techniques and skills as well as conceptual thinking. This is to provide a modern Biology course as well as meet the needs of the learner and the society through relevance and functionality in its contents, methods, processes and applications.

2.3 Problems of Teaching and Learning Biology in Nigerian Senior Secondary Schools

Biology, according to Okenyi (2015), is all the knowledge of living things that has come to us from the past. It is therefore the science of life. Biology education on the other hand, is the act of teaching and learning in order to inculcate or transfer the knowledge of Biology as well as scientific skills and attitudes to the students at any level. It can also be seen as the application of the principles of education in teaching and learning of Biology. Nwagbo (2005) noted that educating people in science especially Biology has been widely acknowledged as a way of promoting economic development, eliminating poverty and introducing social welfare. Although, developing countries like Nigeria, Ghana and others have made efforts to generalize the provision of Biology education at both secondary and higher institution levels, the present teaching and learning in Biology classrooms in Nigeria seem inadequate due to certain challenges. Some of these challenges include:

1. **Quality and Methods of Teaching:** Ayodele (2006) identified the use of inappropriate and non-effective teaching methods as the major factor hindering students' understanding and achievement in science and Biology in particular. According to Agbenyeku (2012), the teaching and learning of Biology do not require theoretical and lecture approaches but numerous studies such as Maikano (2016),

Abubakar (2017) and Musa (2017) have shown that Biology teachers are expository in teaching. These teachers according to Zubairu (2016) teach Biology in abstraction and often do not take into account the different shades of interest and ability levels in the class. This therefore makes Biology lessons boring and the students finding it difficult to grasp some scientific concepts, skills and principles thereby leading to poor performance.

2. **Content Relatability and Relevance:** Olanrewaju (2012) described relatability as the ability of students to associate Biology classroom experiences to everyday life and relevance as how useful such experiences are (to the students) in other settings like career aspiration, the study of other subjects and the understanding of events occurring in the immediate environment. Cimer (2012) identified the lack of relationship between what is taught in the Biology class and the students' daily lives as one of the reasons why students have difficulty in learning Biology. Olanrewaju (2012) further explained that this results in students' demotivation, loss of interest and development of negative attitude towards the subject. Hence, poor performance of students in Biology could be ascribed to the low relatability indices and perceived irrelevance of some of the concepts.

3. **Teacher Quality and Preparedness:** According to Omorogbe and Ewansiha (2013), achieving the goals of science education and by extension, Biology education in Nigeria requires qualified and highly scientifically literate teachers. Okureme (2003) posited that an effective science teacher should be a master of his subject, be well grounded in methods of teaching and be able to relate the science concepts to real life experiences. However, Olanrewaju (2012) opined that most Biology teachers are often unprepared to teach certain concepts in Biology due to their specialization. For instance, some Biology teachers who are Zoology graduates with a Postgraduate Diploma in Education (PGDE) frequently have issues teaching Botany-related concepts. Ibrahim (2015) added that some Biology teachers experience difficulty in teaching Ecology, Genetics and Evolution due to the limited exposure of such teachers to courses in these areas in the university. More so, Okenyi (2015) observed that there is shortage of qualified Biology teachers in Nigerian secondary schools and a good number of the few available ones may have the knowledge but lack the methods. These teachers for many years have failed to upgrade their certificates by going for further studies or in-service trainings which invariably affects their output.

4. **Inadequate Instructional Materials and Teaching Facilities:** One of the reasons students have difficulties learning Biology is the

inadequacy of instructional materials and teaching facilities in schools. Wada (2016) noted that many Senior Secondary Schools in Nigeria do not have standard Biology laboratories and enough teaching and learning materials. As a result, the teachers do not carry out Biology lessons as expected and students find the subject difficult to learn. As stipulated by the NERDC (2012), one of the objectives of teaching Biology is to help students acquire adequate laboratory and field skills, but this cannot be achieved until adequate instructional materials and facilities are provided. Science classrooms, laboratories and the general learning environment must be adequate and conducive. However, as noted by Olanrewaju (2012), the sad reality is that it is at WAEC or NECO examination time that Biology teachers scramble for equipment and materials for Biology practicals because the instruction to supervisors would lead them to the type of practicals that may come out. Omoifo (2012) added that Biology teachers hardly demonstrate phenomena and students rarely carry out experiments or engage in hands-on activities due to lack or inadequacy of instructional materials and laboratory facilities. The problem of inadequate teaching aid is further worsened when the few available ones in some schools are improperly maintained.

5. **Curricular Content:** In the development of Biology education in Nigeria, the role of a befitting curriculum cannot be overemphasized.

However, Olanrewaju (2012) raised four main issues with regard to the content of the Biology curriculum in relation to students' academic performance in the subject. These are topic difficulty, relatability and relevance, content overload and structural incompatibilities. Ribah (2011) on the other hand adjudged the senior secondary Biology curriculum as far from feasible with regard to its target group of users, the time available for its coverage, the facilities available for its implementation, as well as the quality of teachers being produced to implement it. According to Timothy (2013), the least performance among the science subjects of the Senior Secondary School Programme is recorded in Biology due to a host of reasons which include the large number of student enrolment; the relatively poor quality of the students taking the subject; and the difficulty of several topics in the subject for teachers to teach and for students to learn. Two other factors in relation to the curriculum that account for the declining performance of students in SSCE Biology are the overloaded Biology syllabus and the structural incompatibility between the Federal Ministry of Education core curriculum in Biology which is spiral in nature and the WAEC/UTME examination syllabuses that are conceptual in nature (Okebukola in Olanrewaju, 2012; Ribah, 2011; Abubakar, 2017). It is therefore necessary to have a curriculum reform to enhance Biology education development in Nigeria.

6. **Time Allocation:** This refers to the duration of a Biology lesson in the school time table and the number of periods slated for Biology per week. The Federal Ministry of Education (FME, 2013) had stipulated three lesson periods for each science subject per week. These are often divided by the schools into a single period of 40-45 minutes and a double period of 80-90 minutes per week. However, Abubakar (2017) observed that this time allocation is grossly inadequate for Biology owing to the plethora of concepts in the Biology syllabus as compared to other science subjects like Agricultural Science, Chemistry and Physics. In a bid therefore to cover the contents for the term, Biology teachers sometimes have to teach quickly. Teaching so quickly of course, negatively affect students' comprehension of the concepts as they are neither given detailed explanations to clarify their misconceptions nor given enough time to ask questions. Anazodo, Adepoju and Abajemit (2011) added that Biology practical activities which require much time to be undertaken - at least a double period of 80-90 minutes per week - is sadly used by many Biology teachers to copy notes or explain previously copied notes. Similarly, Enohuean (2015) noted that there is also the constraint of available school time. Only about six out of the nine terms in the 3-year programme are essentially used in most schools for meaningful academic work. First terms are widely

known for the absence of serious academic work due to registration activities.

7. **Inadequate Funding:** Okenyi (2015) noted that there is no adequate fund for the provision of conducive and enabling environment to facilitate the effective teaching and learning of Biology in senior secondary schools. According to Ebong (2008), the role of tertiary institutions in teaching and conducting research to enrich the process of social development has also been compromised due to lack of sufficient funds. Meanwhile, research in Biology requires huge capital investments which most individuals cannot shoulder. Abubakar (2017) noted that in most cases, government do not give much attention to funding secondary science education and the little funds disbursed sometimes for that purpose are mostly mismanaged by the school administrators. Lawal (2015) also added that irregularity in the pay of salaries, meagre or lack of science teaching allowances and insufficient funding for Teacher-Vacation Courses all contribute to demotivating Biology teachers from putting in their best at work.

8. **Large Class Size:** Dan-Ologe and Shittu (2008) have identified class size as one of the problems that cause poor performance in science subjects, especially Biology and Chemistry. Large class size, as observed by Anazodo, Adepoju and Abajemit (2011), is undoubtedly a problem to the effective teaching of practical and theoretical

Biology. The National Policy on Education (FRN, 2013) provides that, the recommended number of students per teacher in a Nigerian Senior Secondary School classroom is 40. However, a vast majority of secondary schools admit too many students - weigh beyond the average - which consequently make it uneasy for Biology teachers to effectively administer practical work or manage a Biology classroom session. An instance can be drawn from the population of this study wherein some schools have more than 350 students in a class with no less than 100 students in an arm. Furthermore, some secondary schools make provisions for laboratories and even equip them, but the large number of students they enrol in a class may render these facilities insufficient.

9. **Nature and Cost of Biology Textbooks:** Mohidiu (2008) observed that Biology textbooks are often found to consist of long and complex sentences that are laden with facts. Such structural complexities impose considerable cognitive demands on students. Lebata (2014) pointed out that Biology contains many technical terms in describing its concepts, principles and theories, and is therefore more susceptible to reading difficulties than other natural sciences. Many technical terms are derived from Latin and Greek words which are alien to the learners. Zubairu (2016) added that the high cost of Biology textbooks is another factor that could be responsible for

students' poor performance. The recommended Biology textbooks by the WAEC, NECO and JAMB syllabi cost a fortune and most parents can hardly afford to purchase these textbooks since Biology is not the only subject that students do in school. Musa (2017) noted that Library facilities in schools where students who cannot afford the needed Biology textbooks can borrow such books are grossly inadequate and the and the services are unsatisfactory. Thus, without textbooks to complement and supplement classroom instruction, students are handicapped and come hardly prepared for the SSCE.

10. **Students' Poor Study Habits:** According to Cimer (2012), students' study habit is one of the reasons they have difficulties learning Biology. Balbalosa (2010) stated that good study habits help learners in critical reflection and in skills such as selecting, analyzing, critiquing, and synthesizing which make them perform better than learners with poor study habits. However, Omorogbe and Ewansiha (2013) observed that many students do not study or review previously taught concepts on Biology examination questions on a regular basis. In addition, Abubakar (2017) noted that a good number of students also fail to listen attentively in class as they suddenly lose interest in what their instructors are saying. This might result from the teacher's style of teaching, the nature of topic being taught or the students' negative attitude to Biology. Anazodo,

Adepoju and Abajemit (2011) also noted that in many Nigerian Senior Secondary Schools, Biology practical work is ill-conceived among many students as unproductive. To them, what goes on in the laboratory neither contributes to their learning of Biology nor engage them in doing science in any meaningful sense. Some students even believe that SSCE Biology practicals do not matter much as long as they can get through in the theoretical parts, which is not actually the case.

11. **Security Challenges:** Okenyi (2015) noted that security issues in Nigeria have been worrisome for years now because of the insurgence of the Boko Haram terrorists, Niger Delta Avengers and the Biafra uprising. People in Nigeria live in fear of the uncertainty of death from bomb blasts or gunshots from these terrorists. According to Aina (2010), teachers and students don' t know their fate every day until they retire to bed at night because of terrorists, kidnappers, armed robbers and the so called avengers or freedom fighters. The attacks on secondary schools and higher institutions where students, teachers and lecturers were cold bloodedly murdered still remain fresh in the academic arena. Science infrastructures built with huge amounts of money in which Biology Departments are beneficiaries have been destroyed. Many parents have lost or quitted their jobs and their children eventually have to drop out of schools. Many of these

dropouts are very brilliant and could become future renowned Biology scholars that the country would be proud of.

12. **Corruption:** Corruption has so eaten deep into the Nigerian system and it is manifesting in every sector of the Nation's economy including Education. In Nigeria today it is no longer about what you know but whom you know. According to Okenyi (2015), purchase of Biology equipment for schools are no longer done transparently since it is either the Chief Executives of the schools or many of their relations that will do the supply. In this case they neither supply according to the required specifications nor the required quantity. Sometimes, no supply is made at all. This results in most of the Biology laboratories being stocked up with fake, expired or obsolete equipment and/or consumables or at worst left virtually empty. Okenyi (2015) also added that money meant for staff training are often diverted to personal accounts while selection of those who will benefit from the training is sometimes based on the "whom you know syndrome". All these will bounce back on the quality of Biology teachers and students Nigeria produces. Employment is also no longer based on merit. Those who are qualified to teach Biology are often not given employment because they do not have people at the helm of affairs referred to as "godfathers". Teaching appointments are done

based on nepotism and favouritism and this is affecting the development of Biology education in Nigeria.

2.3.1 Students' Academic Performance in Biology at Senior Secondary Schools

Performance, according to the Oxford English Dictionary (2006) is the accomplishment, execution or achievement of tasks. Lebata (2014) explains that accomplishment of tasks, in the context of the academic function of schools, refers to academic excellence or efficiency which is measured in terms of learner performance in class work and national examinations. In the context of teaching however, performance refers to the teachers' ability to teach consistently with diligence, honesty, and regularity. Lawal (2009) defined academic performance as overall measure of academic achievement of students in a given test after a period of instruction and teaching, usually weighed as a score. In another definition, Adeyemi (2008) described academic performance as the scholastic standing of a learner at a given moment expressed in terms of the grades obtained in a course or groups of courses. Similarly, Obeka, Bichi and Yusuf (2012) considered academic performance as the display of knowledge attained or skill developed in school subjects designed by test and examination scores or marks assigned by subject teacher. Performance however can only be worthwhile when the teaching and assessment of students involves the three major domains of educational objectives, namely: cognitive, affective and psychomotor domains.

A number of researchers across the world like Ogunmade (2005), Lawal (2010), Timothy (2013), Omorogbe and Ewansiha (2013), Lebata (2014), Ibrahim (2015) and Umahaba (2016) are consistent on the fact that students perform poorly in science subjects especially Biology at the senior secondary school level and this has been concern to all and sundry. According to Ogunmade (2005) science teaching in Nigerian schools has been criticised because of the poor performance of Nigerian students in science subjects relative to their counterparts in other countries. Thus, indicating from his study that there exists in Nigeria a gap between actual science teaching and learning and an ideal school science with regards to curriculum, pedagogy and learning, class sizes and resource allocation, teacher knowledge and skills, attitude and professional development, and community support. Lebata (2014) also indicated a poor performance in science subjects especially Biology in some African countries such as Lesotho, Nigeria and Uganda, so much so that it has led to a widely acclaimed fallen standard in science education in these countries.

A specific instance illustrating the poor academic performance of Nigerian students in the Sciences and Biology in particular is the summary review of November/December NECO 2011 results for Physics, Chemistry and Biology examinations presented by Omorogbe and Ewansiha (2013). It reveals that 48,311 candidates sat for Physics of which 99.95% (48,287 candidates) failed (i.e. obtained D7-F9) and only 0.05% (24 candidates) passed at credit level and above; 44,950 candidates sat for Chemistry of which 94.68% (42,373 candidates) failed and only 5.32% (2,577 candidates) passed at credit level and above; while 97,595 candidates sat for Biology of which 92.43% (90,207 candidates) failed and only 7.57% (7,387 candidates) passed at credit level and above.

According to Lawal (2010), Biology is one of the science subjects which have been reported as having downward trend in the performance of students at the Senior School Certificate Examination (SSCE) and in fact, the failure rate in Biology is even more alarming compared to Chemistry and Physics despite the fact that it is the popular science subject among students. In agreement to Lawal's position, Timothy (2013) observed that a review of students' enrolment in science subjects in the senior secondary schools in Nigeria showed that students enrolled more in Biology than other science subjects but their academic achievement in this subject is comparatively low in SSCE. To further support this claim, the WAEC Chief Examiner's Report (2011) stated regarding students’ performance in Biology in relation to other science subjects that when compared to the May/June 2010 WASSCE, there was a decline in the performance of candidates in Biology 1 and no significant difference in the performance of candidates in Biology 2. In addition, the WAEC Chief Examiner’s Report (2012) noted a slight drop in the performance of students in Biology 2 and 3 despite the fact that there had been a steady increase in the number of candidates’ enrolment in the sciences with Biology at the highest.

However, Lawal (2010) observed that a number of reasons have been identified as being responsible for the high failure rate in Biology, prominent among which include the teachers’ use of inappropriate teaching methods, overloaded Biology syllabus, difficulty of topics and some concepts as well as absence of dedication and resourcefulness on the part of the teachers. Lebata (2014) although admitted that Biology performance in SSCE is the poorest among all other science subjects, but in a broader perspective attributed the poor performance in science subjects to poor quality of science teachers whose methods of teaching such as excessive talking, writing of notes and rote learning of textual materials tend to inhibit interest; the prevalent exposition method of instruction rather than inquiry, with very little involvement of learners in experimentation; and shortage of laboratory facilities and equipment necessary for practical work. Hence, to help improve students' performance in these final examinations, Biology and by extension, science, need to be taught effectively. The teachers need to employ methods that will enable the students to learn more, retain more and apply what is learnt by engaging in significant and appealing activities. The Biological Sciences Curriculum Study (BSCS) 5Es Problem-Solving Model, according to Ibrahim (2015) and Umahaba (2016), offers a promising opportunity in this respect.

Nonetheless, with the lingering poor performance of students in Biology, a vast amount of research have been conducted on different groups of students using novel and innovative instructional strategies to see if perhaps the situation can be remedied. The results of most of these researches appear to be promising. For instance, Lawal (2009) worked on the effects of conceptual change instructional strategy on remediating identified misconceptions held by students in Biology and found that students exposed to conceptual change strategy performed significantly better than those taught with the traditional method. Likewise, the work of Lakpini (2012) on the effects of conceptual change instructional strategy on achievement, retention and attitude of secondary school Biology students with varied abilities showed that there was no significant difference in the performance of average ability subjects taught using conceptual change instructional strategy and high ability group subjects taught using traditional method. The findings also revealed that low ability subjects exposed to conceptual change strategy performed significantly better than average ability subjects taught using traditional method and subjects of low ability exposed to conceptual change strategy performed significantly better than low ability subjects exposed to traditional method.

Ibrahim (2012) investigated the effects of levels of teacher-students verbal interaction on academic performance of senior secondary school Biology students and found that students taught Biology using high level of teacher-student verbal interaction performed significantly better than those in the medium and low level of interaction in some Biology concepts. Ajayi and Osoko (2013), in their study on the effects of practical-assisted instructional strategy on students' achievement in Biology, revealed that practical-assisted instruction was more effective in fostering the performance of students in Biology than the traditional Lecture Method. Ibrahim (2015) investigated the impact of 5E teaching cycle on attitude, retention and performance in genetics among pre-NCE students with varied abilities and revealed that pre-NCE Biology students exposed to 5E teaching cycle in the teaching and learning of genetics concepts in all the ability levels had higher mean performance scores and retained more than those in the control group exposed to Lecture Method of instruction. Similarly, Umahaba (2016) conducted a study on the impact of 5Es learning model on questioning style preference and academic performance among secondary school Chemistry students in Katsina Metropolis, Nigeria and revealed that students in the experimental group who received instruction through the 5Es model performed significantly better, academically, than the control group students who were taught using the Lecture Method. The findings also show that the 5Es model enhanced the experimental group students' ability to answer more difficult questions (i.e. enhanced their questioning style preference) than the control group students. In addition, Ihejiamaizu and Ochui (2016) affirmed from their findings on the utilization of Biology laboratory equipment and students' academic performance in Cross River State, Nigeria that utilization of Biology laboratory equipment significantly influenced students' academic performance in Biology. Therefore, the results obtained from these studies collectively imply that a strategy which is student-centered, collaborative, where students are actively involved in knowledge construction has positive influence on students' performance and helps to increase their ability to apply knowledge acquired to solve real life problems.

Hence, one major aim of this study is to find out if exposure of secondary school Biology students to the 5Es Problem-Solving Model will positively affect their academic performance.

2.3.2 Trends of Senior Secondary Students' Performance in Cell Physiology Concepts

Physiology, according to Lawrence (2008) refers to all the normal functions that take place in a living organism. It is a branch of Biology that deals with the functions and activities of life or of living matter (as organs, tissues or cells) and of the physical and chemical phenomena involved. Cell physiology on the other hand, is the biological study of the activities which take place in a cell to keep it alive. These include taking in nutrients, expelling wastes and reproducing. According to Microsoft Encarta (2008) cells must be able to carry out a variety of functions to stay alive. Some cells must be able to move and most cells must be able to divide. All cells however must maintain the right concentration of chemicals in their cytoplasm, ingest food and use it for energy, recycle molecules, expel wastes, and construct proteins. Cells must also be able to respond to changes in their environment.

The concepts under cell physiology in the Nigerian senior secondary Biology curriculum are captured under two broad topics - 'The Cell and its Environment' and 'Some Properties and Functions of the Cell' (NERDC, 2009). The concepts under 'The Cell and its Environment' as stated by the curriculum include: Diffusion and Osmosis while the concepts under 'Some Properties and Functions of the Cell' include:

Feeding Definition and Types; Cellular Respiration; Anabolism - Usefulness of Food; Autotrophy - Photosynthesis and Chemosynthesis; Heterotrophy; Role of Enzymes; Excretion; Growth; Cell Reactions to its Environment; Movement; and Reproduction: Forms of Reproduction.

Researchers across the world like Tekkaya, Ozkan and Sungur (2001), Chattopadhyay (2005), Cimer (2012), Agboghoroma and Oyovwi (2015) and Chatila and Al-Husseiny(2017) have studied students' difficulties in learning Biology and have shown that senior secondary school students either perceive most of the cell physiology concepts as difficult and so have difficulty in learning them. Tekkaya, Ozkan and Sungur (2001) identified Mitosis and Meiosis, Protein synthesis, Respiration, Photosynthesis, Organic and Inorganic Molecules as well as Diffusion and Osmosis as concepts perceived as difficult by Turkish high school students and teachers. Chattopadhyay (2005) identified cell division as difficult among higher secondary students in North-East India. Similarly, Cimer (2012) identified aerobic respiration and cell division as challenging among secondary school students in Turkey. In addition, Agboghoroma&Oyovwi (2015) identified mitosis and meiosis as difficult among secondary school students in Delta State, Nigeria.

More objectively, WAEC Chief Examiner's Reports (2010-2015) highlight a number of cell physiology concepts as being unpopular and often failed among candidates. These include aerobic and anaerobic respiration, mitosis and meiosis, movement, reproduction and excretion. WAEC Report (2010) clearly states that many candidates could not write the correct equations for aerobic and anaerobic respiration. They rather defined the concepts and so lost the marks. Some candidates who attempted the equation could not balance it. Most of them got the reactants correctly but could not correctly list the products. The report also states regarding mitosis and meiosis that many candidates could correctly name the site of meiosis in plants but in animals, they named gonads rather than testes and ovary and so lost some marks. In addition, number of candidates could correctly state the differences between mitosis and meiosis but many candidates' answers did not correspond and so lost marks. WAEC Report (2011) acknowledges most candidates' ability to properly describe the effect of gravity on plant growth but they could not properly describe an experiment to demonstrate the effect of gravity on the roots of plants. WAEC Report (2012) notes that many candidates confused biochemical processes taking place in cells to produce energy with inhalation and exhalation. Candidates could not also give corresponding answers in the differences between the aerobic and anaerobic respiration. WAEC Report (2013) mentions that candidates were able to define respiration but were unable to correctly tabulate the differences between gaseous exchange and aerobic respiration. Most candidates were also able to define photosynthesis but could not give balanced equations and list the external and internal factors that affect the rate of photosynthesis. In addition, many candidates could not list and explain the products of the light dependent stage of photosynthesis. Furthermore, WAEC Report (2015) points out that the question on sexual reproduction and excretion was the least popular among the candidates and most of the candidates that attempted it did not do well. Many candidates according to the report were also writing about photosynthesis instead of giving the structures and stating the functions of each structure as required. One can thus deduce from the above literature that cell physiology concepts are of high perceived difficulty in the secondary school Biology syllabus.

Acknowledging the severity of this situation, Cimer (2012), Agboghoroma and Oyovwi (2015) and Chatila and Al-Husseiny (2017) agree on the fact that experiencing difficulties in many topics in Biology negatively affects students' motivation and achievement and this according to Cimer (2012) has stimulated researchers to investigate why students experience such difficulties and how to overcome them. Among the reasons reported by researchers like Zeidan (2010), Cimer (2012) and Chatila and Al-Husseiny (2017) as to why students experience difficulties in learning Biology include: the nature of biological sciences, the teachers' styles, techniques and methods of Biology teaching, the abstract and interdisciplinary nature of biological concepts, events, topics and facts that students have to learn, the Biology curricula content being overloaded and not generally related to working life, the lack of discussion of topics of students' interest and teachers' negligence of students' expectations, the absence of creative expression opportunities as well as the alienation of Biology from society. Cimer (2012) however sums it up that understanding secondary school student's perceptions of Biology will help policy makers, teachers and teacher educators plan more effective teaching activities that can help students learn Biology better and have more positive attitudes towards it.

2.4 Science Process-Skills Acquisition among Senior Secondary School Students

Science process-skills according to Njoku (2002) are cognitive and psychomotor skills employed in problem solving. They are skills which scientists use in problem identification, objective inquiry, data gathering, transformation, interpretation and communication. They can be acquired and developed through training such as are involved in science practical activities and they are the aspects of science learning which are retained after cognitive knowledge has been forgotten. Their use is an important indicator of transfer of learning which is necessary for problem-solving and functional living. Karamustafaoglu (2003) explained that science process-skills are special skills that simplify learning of science, activate students, develop students' sense of responsibility in their own learning, increase the permanency of learning, as well as teach them the research methods. According to Karamustafaoglu (2011), science process-skills are the thinking skills that we use to get information, think on the problems and formulate the results. They are also the skills that scientists use in their studies. These skills are appropriate for all science fields, and they reflect on the correct behaviours of scientists while they are solving a problem and planning an experiment. They also constitute the essence of the thinking and research within science making it more important for the students to learn them and how to apply them in science than learning reality, concepts, generalizations, theories and laws in science lessons. Omiko (2015) has it that science process-skills enable the students to develop and retain the cognitive, affective and psychomotor aspects of scientific study which will in turn enable them to study and practice science as part of their culture.

Kazeni (2005) noted that the American Association for Advancement of Science (AAAS) did the pioneer work on identification of activities that constitute science process-skills. According to him, the AAAS identified fourteen activities that constitute the science process-skills which are classified into two categories based on operational difficulties and intellectual demands. These categories with their component skills are the basic science process-skills which include; observing, measuring, inferring, classifying, predicting and communication and the integrated science process-skills which include; formulating hypotheses, identifying variables, defining variables operationally, designing investigations, experimenting, analysing data, indicating causes and effect relationship and formulating variables/models. Enebechi (2008) noted however that over the years, authors and researchers have made various modifications of the list of the skills but the list by AAAS still remains comprehensive in its form. According to Omiko (2015), the NERDC had in 1992 recognized and adapted the skills.

According to Nweke (2015) not much has been done in Nigeria to provide specific instructional and assessment programmes to facilitate the development of science process skills both at the primary and secondary school levels and by the central examining bodies like WAEC. Omiko (2015) also observed that assessment of possession of science process-skills has so far been intrinsic in nature in relation to other facts of the contents of science subject domains. WAEC Chief Examiner' s Reports (2014) show that the poor performance in the science subjects are largely due to poor performances in practical aspects of science. Omiko (2015) and Nweke (2015) were of the same opinion when they observed that poor performance in practical work is synonymous with poor performance in science process skills since generally, SSCE candidates show weakness in questions involving the application of acquired science process skills. Many factors as observed by Omiko (2015) have been adduced for the poor acquisition of science process-skills among which is the teacher's use of inappropriate teaching methods. According to him, the extent to which the students are able to develop science process-skills depend largely on the instructional technique employed by the teacher in the teaching of science.

Research such as those of Karamustafaoglu (2011), Nwagbo and Chukelu (2011), Banfe (2013), Usman, Ahmed and Tijjani (2014), Omiko (2015), Guevara (2015) and Duniya, Olorukooba, Usman and Obeka (2016) have shown that participating in inquiry-based activities in science classrooms at all educational levels helps students to realize the science process-skills. In the work of Karamustafaoglu (2011) which was carried out to identify the level of science and technology student teachers' science process skills and to determine how efficient I-diagrams are in developing these skills, the results revealed that the student teachers had problems with the pretests, especially with the integrated process-skills but at the end of the study, it was observed that the student teachers' skills on developing I-diagrams increased and their integrated process-skills problems disappeared. This implies that I-diagrams are important for the acquisition and development of science process-skills.

Nwagbo and Chukelu (2011) worked on the effects of Biology practical activities on secondary school students' process-skills acquisition in Abuja Municipal Area Council and revealed from the findings that practical activity method was more effective in fostering students' acquisition of science process-skills than the Lecture Method implying that activity-based methods enhance understanding of biological concepts and increase the ability to acquire science process-skills by the learner. Banfe (2013) investigated the effects of small class-size interaction on the acquisition of science process-skills in Integrated Sciences among junior secondary students using Amma International Secondary School, Potiskum as a case study and revealed from the findings that students taught science process-skills using small class-size interaction achieved more than the students taught science process-skills using large class-size interaction implying that the use of small class-size (group) interaction in practical classes (activities) enhances the students' acquisition of science process-skills.

Usman, Ahmed and Tijjani (2014) studied the effects of Biology practical activities on SS2 Students' process skill acquisition from selected senior secondary schools in Sabon-Gari Local Government Area of Kaduna State and revealed from the results that practical activity method was more effective in fostering students' acquisition of science process skills than the Lecture Method. In the study of Guevara (2015), the effects of combining innovative approaches in teaching general Biology on the development of students' science process-skills was examined among college non-science freshmen from a government-managed higher learning institution in the Philippines and the results showed significantly higher scores in the science process‑skills of students exposed to the multiple representations and collaborative learning approach compared to those exposed to traditional or expository teaching approach. The findings also revealed that for students exposed to innovative teaching approach, science process-skills cannot be correlated with their prior science knowledge. These therefore imply that the use of multiple representations collaborative approach fosters significant improvement in students' science process-skills with the strength of the effect having no significant bearing on prior knowledge.

Duniya, Olorukooba, Usman and Obeka (2016) investigated the impact of laboratory instruction on science process-skills acquisition in Biology among convergent and divergent secondary school students. Findings from the study revealed a significant difference between the convergent and divergent students exposed to laboratory instruction (experimental groups) and those exposed to Lecture Method (control groups) with respect to science process-skills acquisition in favour of the convergent and divergent experimental groups. There was however no significant difference in the science process-skills acquisition between the convergent and divergent students exposed to the Lecture Method. By implication therefore, the laboratory instruction method is a more effective instructional strategy when compared with Lecture Method. In addition, Chatila and Al-Husseiny (2017) investigated the effect of cooperative learning in Biology classroom on students' acquisition and practice of scientific skills among students of grade seven and ten and illustrated from their findings that cooperative learning has a significant effect on students' achievement in learning and practicing scientific skills in grade ten. However, no significant effect was seen in the acquisition of new scientific skills for grade seven students.

Similar results were also recorded by Chebii, Wachanga and Kiboss (2012), Yadav and Mishra (2013), Abungu, Okere and Wachanga (2014), Sen and Sezen-Vekli (2016) as well as Ghumdia (2016) on the efficacy of various inquiry-based strategies in fostering the acquisition of science process skills among students. It is therefore the aim of this study, to determine the impact of 5Es Problem-Solving Model on the acquisition of science-process skills among secondary school Biology students in Zaria Education Zone of Kaduna State, Nigeria.

2.4.1 Relevance of Science Process-Skills to Science Education

Science process-skills have been described by Usman, Ahmad and Tijjani (2014) as a broadly transferrable set of skills that reflects the working behaviour of scientists. According to Ozgelen (2012), they are the thinking skills that scientists use to construct knowledge in order to solve problems and formulate results. These skills, as noted by Kazeni (2005), had been developed by the AAAS in 1991 and grouped into two broad categories based on their operational difficulties and intellectual demands to include the "basic" and "integrated" science process-skills. Researchers such as Rehorek (2004), Aktamis and Ergin (2008) and Karamustafaoglu (2011) have examined the components of both categories and drawn a number of significance and applicability for the science process-skills.

First and perhaps the most important significance of the science process-skills is that they're fundamental in problem solving. According to NARST (2014), science process skills governs and drives the scientific method, which provides a basis for undertaking scientific research - the essence of which is to solve specific problems. Along the same lines, Rehorek (2004) had observed that, the development of science process-skills enable students to construct and solve problems in research laboratories. In addition, Usman, Ahmed and Tijjani (2014) states that the scientific process is one of three aspects of science (i.e. scientific process, products and attitudes) and the skills which constitute the scientific process (i.e. the science process-skills) are learnable, transferrable and applicable in both science and non-science situations to solve problems. In other words, the science process-skills are not only useful in the laboratories but can be and are often utilised in our day to day lives to solve problems or address challenges.

Secondly, the science-process skills positively enhance cognitive and critical thinking skills. Ozgelen (2012) noted based on conclusions from multiple research findings that, a positive correlation exists between science process-skills acquisition and the conceptual framework of the cognitive domain which include information processing skills, reasoning skills, inquiry skills, creative thinking skills and problem solving skills. Therefore, it is expected that individuals who have acquired and utilise the science process-skills are able to address complex cognitive challenges as well as think logically and coherently when faced with intellectually puzzling issues - all of which are required in vital decision making. Along the same lines, Rehorek (2004) observed that the development of science process-skills enable students to think critically as well as decide and find answers to their curiosity. Karamustafaoglu (2011) further added that the ability to use the basic science process-skills is attributed to the ability to perform "empirical-inductive reasoning" or the Piaget's concrete operational reasoning while the ability to carry out integrated science process-skills is attributed to “hypothetico-deductive resoning” or the Piaget’s formal operational reasoning.

Science process-skills also help stimulate scientific creativity in students. Scientific creativity has been clearly defined by Dass (2004) as the ability of an individual to recognize the gaps in a problem or information, create ideas or hypotheses, test and develop these hypotheses and transmit the data. This definition, as observed by Aktamis and Ergin (2008), could be adjudged to be similar to that of the science process skills as both are resulting from the necessity of eliminating a problem in daily life. Therefore, creativity can be accepted as an important aspect of the scientific skill. To further buttress this point, a study was conducted by Atkamis and Ergin (2008) to investigate the effects of teaching scientific process skills on students’ scientific creativity, attitudes towards science and academic achievement. It was determined in that study that the scientific process-skills education increased students’ achievement and scientific creativities, however, no significant progress was made on their attitudes towards science when compared to the teacher-centered method. It is therefore of interest in this study to determine whether the acquisition of science process-skills, knowledge retention and performance of secondary school Biology students can be impacted by the use of the 5Es Problem-Solving Model.

2.5 Instructional Strategies in the Teaching and Learning of Biology

There are various definitions of instructional strategies in science education. Ofoegbu (2003) defines instructional strategies as the study of the various means or ways of teaching. Shaibu (2008) sees it as a process of giving, exchanging or sharing of facts, information, ideas, skills, behaviour and attitudes that ultimately lead to noticeable and desirable behavioural changes in the individual.

In the teaching of Biology concepts, there exist today many approaches or methodologies that can be used depending on the knowledge, skills and attitudes intended to be imparted. Some of these methods as identified by Reid and Shahi (2007), Ezeaghasi (2014), Shuaibu (2017) and Abubakar (2017) include Laboratory Method, Lecture Method, Demonstration Method, Discussion Method, Discovery Method, Enquiry Method and Field Trip Method among others. These are discussed in details below:

I. **Laboratory Activity Method**: This is a method of teaching where by tools, apparatus and instructional materials are used to stimulate and enhance the process of learning in a place known as the laboratory. As noted by Ezeaghasi (2014), laboratory work in Biology involves observation, description or drawing, microscopy, dissection and experimental work. In the teaching and learning of Biology, scholars like Reid and Shahi (2007) hold the opinion that laboratory work gives the students the opportunity to experience science by using scientific research procedures as well as encourages the development of analytical and critical thinking skills in them. Laboratory work according to Shuaibu (2017) also strengthens theoretical knowledge, the development of their psychomotor skills as well as pleasure of discovery. It increases creative thinking skills, higher order thinking skills and the development of manual dexterity by the use of tools and equipment, allowing students to apply skills instead of just memorizing facts.

II. **Lecture Method:** Thisis a method used primarily to introduce students to a new subject, but it is also a valuable method of summarizing ideas, showing relationships between theories and practice and re-emphasizing the main points. Abdullahi (2012) observed that many teachers use this teaching method almost exclusively as it is considered the simplest and one can cover large amount of material in a short period of time. According to Abubakar (2017), a lecture can be an effective method for communicating theories, ideas and facts to students. The main aim of every teacher is to make sure that he/she communicates effectively with his/her students. In order to do so, a teacher should try to achieve clarity of delivery, clarity of expression and clarity of structure. Mani (2008) postulated that if Lecture Method is to be used, it should be applied on matured groups of students who can jot down points during instruction and a list of reference books should be provided by the instructor to help students read further and make notes on their own. Shuaibu (2017) added that in this method of teaching Biology, the teacher needs to understand the size of the audience, the instructional material to be used, how to maintain an effective classroom environment and the interest of the students. The teacher also needs to organize the instruction to be delivered to students so as to avoid complexity and confusion during presentation of the lessons.

III. **Demonstration Method**: This is a method of teaching in which sight rather than hearing is the major means of communication, though the two are often combined (Abubakar, 2017). It is often effective because, most people easily remember what they see than what they read or hear about. According to James and Usman (2000), Demonstration Method is one of the teaching methods that involve mental skills for learning such as observing, measuring, classifying, formulating hypothesis, experimenting, data collection, data analysis and drawing conclusions. Obeka (2010) noted that it is a method where by the teacher illustrates concepts with hands-on activities and relevant examples. Demonstration can be carried out by the teacher alone, the teacher with a student, the student who is knowledgeable in the activity or an invited guest (NTI 2006). According to Mahuta (2013), the demonstrator is like a mirror as he shows, while students observe. The process of demonstration is a physical display of objects, models, pictures, and diagrams. When students learn through Demonstration Method, they concretize learning and the comprehension lasts longer (Ezeaghasi, 2014).

IV. **Discussion Method**: This is another method of developing cognitive and affective strategies in Biology teaching (Reid & Shahi, 2007). Abubakar (2017) stated that it is a method of teaching where the teacher and students engage themselves in lively discussions of a topic and both parties give their views on the topic. According to Dawuda (2014), Discussion Method is a student centered method of teaching in which students participate actively in the in the discussion process over a subject matter or a topic from various points of view, while the teacher act as a moderator or guide. This method facilitates effective flow of information from the teacher to the students; from the students back to the teacher and from one student to another (Haas 2002). Sanusi (2012) opined that Discussion Method provides a variety of forums for open-ended, collaborative exchange of ideas among teacher and students or among students for the purpose of furthering students thinking, learning, problem solving, understanding and literary appreciation. In using this method, Obeka (2013) noted that the teacher should do the following:

- choose a learners' interest-oriented topic which should also be thought-provoking and argumentative;
- assign roles among participants;
- try as much as possible to decide ahead the type of discussion that the learners will take part in;
- lead and guide the learners to stick to a particular point in discussion activities;
- make sure that the learners are effectively motivated to be attentive in the discussion; as well as
- encourage the learners to ask questions in the areas where they have problem.

V. **Discovery Method**: This is a technique that encourages students to be more active in their learning process by answering a series of questions and solving problems. Mayer (2003) noted that Discovery Method is based on the notion that learning takes place through classification and scheme formation. Gallenstein (2004) posited that discovery is essential as students are actively involved in the process of learning and topics are intrinsically motivating. According to Ezeaghasi (2014) the context of discovery is often more meaningful than typical classroom exercises as students acquire investigative skills, new strategies are learnt and students are more likely to remember concepts and information if they discover them on their own.

VI. **Enquiry Method**: According to Abubakar (2017), enquiry is a term used in science teaching which refers to a way of questioning, seeking knowledge or information or finding out about phenomena. It involves investigation, searching, defining a problem, formulating hypothesis, gathering and interpreting data and finally arriving at a conclusion. Mani (2008) observed that this method has different names given to it by different scholars such as Problem Solving, Critical Thinking, Reflective Inquiry and Inductive Thinking. Mahuta (2013) stated that Discovery Method provides the opportunity for the learners to seek knowledge in a systematic and logical way as well as provide the students with the opportunity to examine ideas, events and problems about a particular concept or situation. It is a method of teaching were the learner, with minimum guidance from the teacher, seeks to find out and create answers to a recognized problem through procedures of making a diligent search (Haas, 2002). Shuaibu (2017) observed that in this method of teaching, the teacher does not provide answers to the learners but tries to direct and guide then to the answers. Abubakar (2017) added that in enquiry situation, students learn not only theories and principles but self-direction, responsibility and social communication. It also permits students to assimilate and accommodate information.

VII. **Excursion/Field Trip Method:**Ezeaghasi (2014) described this method is an important component of science teaching which involves taking students outside the classroom for the purpose of making observations or obtaining specific information. According to Wakili (2007) Field Trip / Excursion Method is a method that involves travelling out of the school environment to a place designed or selected for learning purposes such as a historical town, an educational resource centre, a game reserve, herbarium, botanical garden, zoo, industry or other interesting places. This is usually arranged and conducted by the school in order to improve the knowledge of students. Mahuta (2013) noted that students often have a long lasting memory when they travel and see events and places for themselves.

In conclusion, it is important for this particular study that the method employed should be effective in promoting science process-skills acquisition as well as academic performance and knowledge retention among students. One such promising strategy as indicated by Jack (2017) is the BSCS 5Es Problem-Solving Model.

2.5.1 The Concept of 5Es Instructional Model

The 5Es instructional model according to Erickson and Verstynen (2017) describes a teaching sequence that helps students build their own understanding from experiences and new ideas and can be used for entire programs, specific units and individual lessons. The National Institute of Health (NIH, 2017) describes this model as an inquiry-based learning cycle that sequences learning experiences so that students have the opportunity to construct their understanding of a concept over time. By inquiry, it means that the model provides a built-in structure for creating and promoting an active, collaborative and constructivist classroom where students are not involved in mere listening and reading but are rather developing skills, analysing and evaluating evidence, experiencing and discussing, talking to their peers about their own understanding and working collaboratively with others to plan investigations and solve problems. In fact, NIH (2017) noted that many students learn better when they work with others in a collaborative environment than when they work alone in a competitive environment.

The 5Es instructional model was developed by the Biological Sciences Curriculum Study (BSCS) in 1987 and was based on the constructivist view of learning which according to Colburn (2003) embraces the idea that learners bring with them preconceived ideas about how the world works and try to test new ideas against that which they already believe to be true. If the new ideas seem to fit in with their pictures of the world, they have little difficulty learning the ideas; if the new ideas don't seem to fit the learners' picture of reality then they won't seem to make sense and may have to dismiss them or eventually accommodate the new ideas and change the way they understand the world. Therefore, the constructivist approach to learning as noted by the Corporation for Public Broadcasting (CPB, 2002), have learners build new ideas on top of their old ones or synthesize new understanding from prior learning, new information and new experiences.

The model according to NIH (2017) leads students through five phases of learning that are easily described using words that begin with the letter E: Engage, Explore, Explain, Elaborate, and Evaluate. The five phases of the model are designed to facilitate the process of conceptual change in students, bring coherence to different teaching strategies, provide connections among educational activities and help science teachers make decisions about interactions with students (BSCS, 2006). Bybee, Taylor, Gardner, Scotter, Powell, Westbrook and Landes (2006) gave a concise explanation to the sequence of five learning phases that constitute the BSCS 5Es Instructional Model which is illustrated in Figure 2.1:

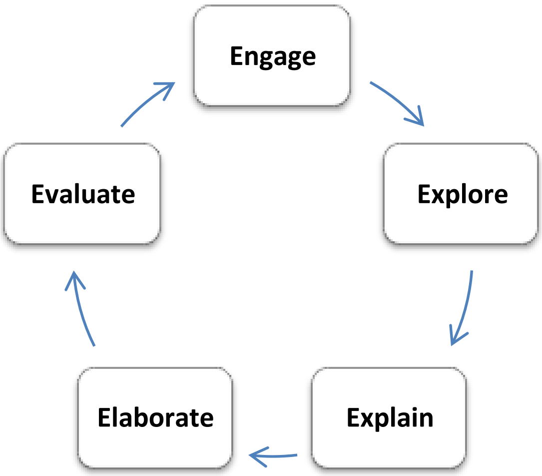

Figure 2.1: An Illustration of the BSCS 5Es Instructional Model (Bybee et al., 2006).

According to Bybee et al (2006), in the **engagement** phase, the teacher or a curriculum task accesses the learners' prior knowledge and helps them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of current activities. **Exploration** experiences provide students with a common base of activities within which current concepts (i.e. misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation. The **explanation** phase focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviours. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them toward a deeper understanding, which is a critical part of this phase. In the **elaboration** phase, teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities. The **evaluation** phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.

The treatment in this study was based on the 5Es Instructional Model which sequences learning experiences so that students have the opportunity to construct their knowledge and understanding of a concept during the teaching-learning process (Bybee, 2002). These phases are as described by Bybee (2002) and Llewellyn (2005) as follows:

Phase 1 – Engagement Phase: The teacher captures students' interest and makes them curious about the topic and concepts to be learnt. This phase provides an opportunity for the teacher to find out what students already know or think they know about the topic and concepts to be developed.

Phase 2 – Exploration Phase: Students interact with materials and ideas through classroom and small group discussions. This helps the students to acquire a common set of experiences so that they can compare results and ideas with their classmates.

Phase 3 – Explanation Phase: Students are provided an opportunity to connect their prior experiences with current learning and generate knowledge from main ideas. This phase also provides the opportunity for the introduction of formal language, scientific terms and content information that might make students' prior experiences easier to describe.

Phase 4 – Elaboration Phase: Students are provided with the opportunity to apply introduced concepts to new experiences. This phase helps students to make conceptual connections between new and prior experiences, connect ideas and deepen their understanding of concepts and processes.

Phase 5 – Evaluation Phase: This phase is centrally placed in the model and takes place in virtually every phase of the 5Es teaching (or learning) cycle. It provides a summative assessment of what students know.

The flowchart for the 5Es Instructional Model is presented in Figure 2.2.

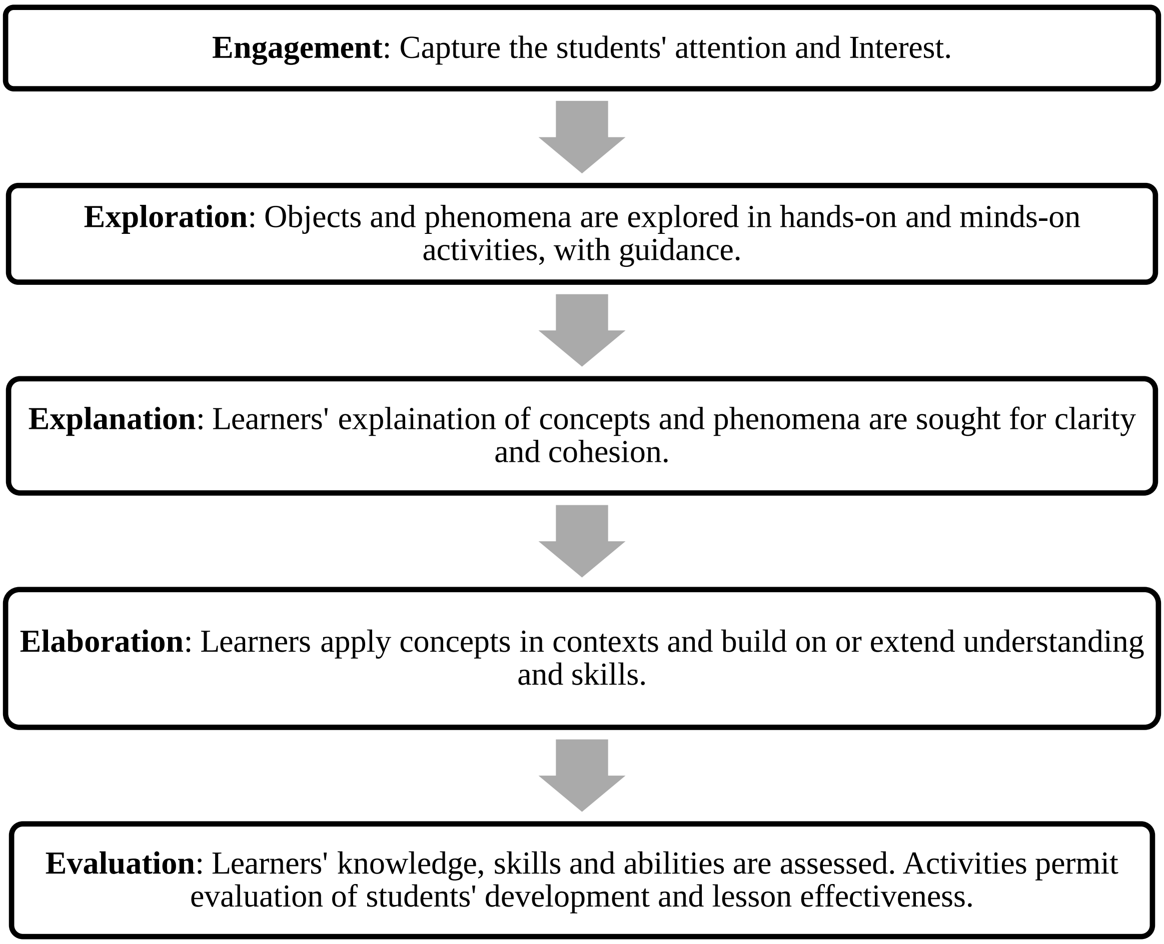

Fig 2.2: Flowchart of the 5Es Instructional Model.

Source: Bybee, et al. (2006)

According to Senan (2013), the 5Es instructional model requires students to do more than simply progress through a series of exercises sequenced to cover certain science topics within a specified period. It rather aims to expose students to major concepts in science as they arise naturally in problem solving. Determining its efficacy in fostering students' acquisition of science process skills and enhancing their academic performance and knowledge retention in Biology compared to the conventional method is the thrust of this study.

2.5.2 5Es Instructional Model and Academic Performance in Biology

A considerable number of studies such as Ajayi and Osoko (2013), Lebata (2014), Ibrahim (2015), Wada (2016) and Abubakar (2017) as well as examination bodies like WAEC (2010-2017) and NECO (2013-2017) have noted the prevalent and lingering poor academic achievement of Nigerian students in science subjects especially Biology at SSCE. This has been attributed by the researchers and examination bodies to so many factors among which is the persistent use of the Lecture Method which is teacher-centered, authoritative, unstable, ineffective and unproductive to the teaching and learning of Biology in the 21st century. Ajayi and Osoko (2013) noted that science teaching in Nigerian secondary schools lays extreme emphasis on content and many science teachers prefer the traditional expository or 'chalk and talk' method wherein they shy away from activity-oriented teaching strategies such as inquiry method, discovery method, cooperative learning strategies, problem-solving strategies, investigatory laboratory approach among others which are student-centered. As a consequence, this negligence and 'shy-away' attitude from activity-oriented methods of instruction has led to abstraction, made students less active in classrooms, made students more prone to rote memorization, resulted in falling achievements, loss of interest and growth of negative attitude to Biology. However, Opara (2011) opined that to perhaps improve the students' academic performance in Biology, a shift will be necessary from what has traditionally been experienced in Nigerian classrooms toward more inquiry-based teaching practices which facilitate teaching for meaningful learning.

The 5Es Problem-Solving Model according to Ibrahim (2015) is an inquiry-based, constructivist-oriented teaching or learning cycle that provides opportunity for students to experience interactive learning and acquire processes through which they can gather information and create new understanding about the world around them. It requires high level of interaction among the learner, teacher, content or area of study, available resources and learning environment. During the 5Es learning cycle instruction, students are allowed to describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge and communicate their ideas to others. The students use the inquiry process to develop explanations from their observations by integrating what they already know with what they have learnt. The 5Es instructional model affords students the opportunity to learn difficult Biology concepts and skills and how to solve problems using practical approaches.

A good number of research have been done to test the efficacy of the 5Es instructional model in learning Biology concepts and how it has affected performance among students in secondary and tertiary institutions. Worthy of first mention is the research carried out by the developers of the 5Es instructional model, BSCS (2006), titled the 'BSCS Science: An Inquiry Approach'. Its findings revealed that students that received the BSCS science program had higher gains on standardized tests and by the end of the 10th grade, BSCS students were 4 months ahead of those in the Comparison Group. The BSCS program also helped teachers use more effective practices. In another study, Balci (2006) investigated the effects of the 5Es learning cycle model, conceptual change text and traditional instruction on 8th grade students' understanding of photosynthesis and respiration in plants. The results showed that there was a significant difference between experimental and control groups in favour of experimental groups with respect to students' understanding of photosynthesis and respiration in plants. On the other hand, there was no statistically significant difference between the students who were instructed with the 5Es learning cycle model and those who were instructed with the conceptual change texts with respect to their understanding of the concept.

In the study of Kaynar (2007), the effectiveness of the 5Es cycle on 6th grade students' understanding of cell concepts, their attitudes toward science and their scientific epistemological beliefs was investigated. Its findings revealed that students in the experimental group who were engaged in 5Es learning cycle instruction demonstrated significantly better performance over the control group students who were engaged in traditional instruction in students' understanding of cell concepts and epistemological beliefs. Ndioho (2007) also investigated the effect of constructivist-based instructional model on senior secondary students' achievement in Biology using the 5Es learning cycle. The result showed that the constructivist instructional approach was significantly more effective in increasing students' academic performance than lecture method.

Ozlem and Jale (2010) investigated the effectiveness of 5Es learning cycle instruction on 11th grade students' Human Circulatory System achievement. Two teachers and four classes with a total of 60 11th grade students participated in the study. Analysis with ANOVA revealed that 5Es learning cycle instruction improved students' achievement in human circulatory system compared to traditional instruction. In addition, Ibrahim, (2015) investigated the impact of 5Es teaching cycle on attitude, retention and performance in genetics among pre-NCE Biology students of different ability levels in North-West Zone, Nigeria. The findings of the study showed that pre-NCE Biology students exposed to 5E teaching cycle in the teaching and learning of genetics concepts in all the ability levels had higher mean performance scores and also retained more than those in the control group exposed to the lecture method of instruction. The attitude of the experimental group improved significantly in all the three ability levels.

Likewise, positive outcomes were recorded in the meta-analysis studies of Anil and Batdi (2015), Ayaz and Sekerci (2015), Ural and Bumen (2016), Sarac (2017) and Cakir (2017) with a broad, positive and significant effect of the 5Es Instructional Model on academic achievement of students. On the contrary, Keskin (2008) and Yildiz, Ergin and Kocakuluh (2012) have reported negative impacts of 5Es Instructional Model on the academic achievement of students. The focus of this study is therefore, to find out whether secondary school Biology students will achieve better in cell physiology concepts when exposed to the 5Es instructional model. It is also of great interest in this study to determine the efficacy of the 5Es instructional model on acquisition of science process-skills among secondary school Biology students.

2.5.3 5Es Instructional Model and Process-Skills Acquisition

The 5Es instructional model according to Ibrahim (2015) allows students to learn and experience Biology first-hand by taking on the roles of scientists through the exhibition of certain skills – the science process-skills. Being an inquiry-based and constructivist-oriented learning cycle model for designing series of experimentally rich lessons that are conceptually linked and developmentally sequenced to support the progressive refinement in students' understanding over time, the constructivist teacher can foster better experiences with the 5Es instructional model in various ways. For instance, through setting up problems and monitoring student exploration, guiding student inquiry and promoting new patterns of thinking (CPB, 2002). Working mostly with raw data, primary sources and interactive material, constructivist teaching according to CPB (2002) requires that students learn to direct their own explorations which ultimately makes them begin to think of learning as accumulated evolving knowledge. Hence, in adopting the 5Es model in classroom instruction as explained by Ibrahim (2015), teachers act as catalysts rather than dispensers of information. They offer students problems, issues and questions and then provide encouragement for inquiry into the nature of the problems and guidance for seeking solutions. Therefore, the 5Es instructional model promotes strategies for inquiry as well as the skills, values and attitudes that are essential to an inquiring mind including process-skills (observing, measuring, classifying, inferring, predicting, communicating, collecting and organizing data, formulating and testing hypotheses, identifying and controlling variables, experimenting etc.), active and autonomous learning, verbal expressiveness, tolerance of ambiguity, persistence, logical and creative thinking, knowledge application and problem-solving (Senan, 2013; Ibrahim, 2015).

Although a few literatures with empirical evidence exist on the effects of 5Es Instructional Model on science process-skills acquisition, worthy of first mentioning is the work of Hirca (2015) who developed and suggested a proposal for primary school teachers (PSTs) in Turkey to teach science and science process-skills without focusing on "structure" of experiments based on constructivist 5Es model. The study was due to Hirca's observation that a large number of prospective primary teachers (PPTs), by virtue of their background, feel anxious about doing science experiments. Some "extended" simple science experiment (ESSE) samples were implemented on 39 PPTs according to the proposal. Then 39 PPTs were allowed to design and to conduct several ESSE. Finally, they assessed their ESSE experiences. They concluded that ESSE is not only easy and enjoyable to engage in, but useful for teaching and learning science concepts and science process-skills.

Cakir (2017) undertook a Meta-Analysis Study to evaluate the Effect of 5E Learning Model on Academic Achievement, Attitude and Science Process-Skills among students in Turkey. In this evaluative research, all the Master's, doctoral theses and articles in Turkish and English languages which were carried out in Turkey between 2006 and 2016 and which are suitable for the research problem were included in the scope of the study. The results revealed that the 5E learning model a positive and significant effect on the science process skills acquisition when compared to traditional teaching methods. From the studies analysed by Cakir (2017), the finding was corroborated by Acisli, Turgut, Yalcin and Gurbuz (2009), Altun, Acisli and Turgut (2010), Acisli and Turgut (2011), Biyikli (2013), Acisli (2014) and Ozturk, Geren and Dokme (2015).

It can be deduced from the above review that only a limited number of researches have been conducted on the effect of 5Es Instructional Model on science process-skills acquisition in Nigeria. This research is however set to contribute to the existing empirical studies on the impact of 5Es Problem-Solving Model on science process-skills acquisition among secondary school Biology students in Nigeria.

2.5.4 5Es Instructional Model and Retention Ability of Secondary School Students.

Retention is defined by Jiya (2011) as the ability of the memory to store information which can be recalled sometime after exposure to series of instruction or training. Beer (2010) noted that it is a tool employed by learners to assist them perform effectively and efficiently in all aspects of life and particularly in the school. Retention of knowledge is in fact a very important factor in the teaching and learning of science. Alongside conceptual understanding, it constitutes the product of meaningful learning and effective teaching (Bichi, 2002). Agbenyeku (2012) explained that retention of concepts learnt would help in reflective thinking and the transfer of knowledge or its application in creative ways to solve day-to-day problems. Several factors influence retention. These include: the individual's information storage capacity, processing efficiency, the ability to combine storage and processing, the ability to inhibit irrelevant information, the quality of knowledge representation and the ability to use efficient strategies in the face of interfering processes and distractions (Abubakar, 2017). Agbenyeku (2012) outlined four factors affecting students' retention of learnt concepts in relation to their academic achievement in Science to include: the thinking style of the individual learner, age of the learner, nature of materials to be learned and teacher's method of teaching.

In literature, only a few studies such as Akinbobola and Folashade (2009), Bunkure (2012), Ibrahim (2015) and Anil &Batdi (2015) have been undertaken to examine the effect of 5Es Instructional Model on Retention of scientific concepts among students. Akinbobola and Folashade (2009) who compared the effectiveness of Constructivist Teaching Methods and the conventional method with reference to achievement, retention and attitude and found that students exposed to Constructivist Teaching Method had higher cognitive achievement, more positive attitude and higher retention level than those taught using the conventional teaching method. Bunkure (2012) revealed that the use of 5Es Teaching Model compared to the traditional Lecture Method, better enhances the retention of learnt Physics concepts among Senior Secondary School students in Kano State, Nigeria. Ibrahim (2015) showed that Pre-NCE Biology Students of North-Western Nigeria exposed to 5E Teaching Cycle in all their ability levels had higher mean retention scores in Genetics concepts than those in the control group exposed to Lecture Method of instruction. Furthermore, Anil &Batdi (2015) in their comparative meta-analytic study of the effect of 5E Learning Model and traditional approaches on students' academic achievement, retention and attitude in Turkey revealed that students' retention scores when taught with 5E Model were better than when traditional teaching methods were used. To further corroborate these findings, Boddy, Watson and Aubusson (2003) assert that using the 5Es instructional model in science teaching helps students to retain better concepts in their minds. Ergin (2006) indicated that students exposed to the 5Es Instructional Model recorded a significantly higher mean retention score when compared to those not so exposed. Sakalli (2011) also found that the constructivist 5Es Model significantly influenced the retention of students in the subject of complex numbers.

However, a gap still exists in literature on the availability of sufficient empirical backing for the efficacy of 5Es Instructional Model on students' knowledge retention especially among Nigerian Senior Secondary School students. Recognizing this gap, this study therefore seeks to determine among other objectives, the impact 5Es Instructional Model could have on retention of Cell Physiology Concepts among Secondary School Biology Students in Zaria Education Zone, Kaduna State, Nigeria.

2.6 Gender and Academic Performance in Biology

Gender issues in science, and in particular, Biology education has been the concern of many educators and series of researches have been going on in this area (Ibrahim, 2015). Research on the effects of students' gender on academic achievement have so far been inconclusive as some findings indicated that gender can influence students' achievement especially in science-oriented subjects while other findings showed that gender factor had no impact on the students' performance (Ajayi &Osoko, 2013). Gender according to Bichi (2002) and Umar (2013) is the amount of masculinity or femininity in an individual. Okeke (2008) also described gender as the socially and culturally constructed characteristics and roles which are ascribed to male and female in any society.

Researches on gender and academic performance such as those of Ige (2001), Raimi and Adeoye (2002), Aigbomian (2002), Njoku (2004), Usman (2008), Ibrahim (2012), Olorukooba, Lawal and Jiya (2012) and Umar (2013) revealed that boys achieved better than girls. On the contrary, studies by Bichi (2002), Adedayo (2004), Atadoga (2005), Lawal (2009), Bunkure (2012) and Dahiru (2013) pointed out that girls achieved better than boys. However, a number of other studies like Lakpini (2006), Ceylan (2008), Hiccan (2008), Bunkure (2012), Ajayi and Osoko (2013), Ibrahim (2015) and Maikano, Bichi and Shaibu (2016) revealed no significant difference in the performance of male and female subjects. Ceylan (2008) investigated the effect of 5E learning cycle on gender in students' understanding of state of matter and solubility concepts. The results revealed that there was no significant mean difference between male and female students in understanding state of matter and solubility concepts. Hiccan (2008) also found no gender difference with respect to understanding of mathematics concepts when taught with 5E learning cycle.

With respect to Biology, the work of Lakpini (2006) on the effects of conceptual change instructional strategy on achievement, retention and attitude of secondary school Biology students with varied abilities showed that no gender difference existed when students were exposed to conceptual change instructional strategy. Lawal (2009) worked on the effects of conceptual change instructional strategy in remediating identified misconceptions held by students in Biology and found no significant difference in the performance of male and female when taught using conceptual change instructional strategy. However, significant gender differences existed among the control group subjects who were exposed to the traditional instructional strategy. The findings also revealed that gender has no significant effect on the retention ability of students when taught using the conceptual change instructional strategy. Ajayi and Osoko (2013), in their study on the effects of practical-assisted instructional strategy on students' achievement in Biology, established that there was no significant difference in the mean Biology achievement scores of male and female students when exposed to the activity-based strategy and that there was no significant interaction effect between instructional strategy and gender in respect to achievement in Biology.

Ibrahim (2015) investigated the impact of 5E teaching cycle on attitude, retention and performance in genetics among pre-NCE students with varied abilities revealed that male and female in all the ability groups exposed to 5E teaching cycle performed equally well and had also no difference in their retention abilities. The attitude of those exposed to the 5E teaching cycle improved significantly in all three ability levels. Similarly, Umahaba (2016) examined the impact of 5Es learning model on questioning style preference and academic performance among secondary school Chemistry students in Katsina Metropolis and found out that the model has no significant effect on gender in relation to their questioning style preferences and academic performance, implying that the model is gender friendly. In addition, Maikano, Bichi and Shaibu (2016) examined gender-related differences in the academic achievement of male and female students taught ecology using the outdoor and indoor instructional strategies among senior secondary Biology students in Giwa education zone of Kaduna, Nigeria and discovered that there was no disparity in the academic achievement of male and female students exposed to both the indoor and outdoor laboratory instructional strategies implying that both teaching methods are gender friendly.

Therefore, this study among other things is set to find out if there are significant differences between male and female senior secondary school students in their academic performance, retention and process-skills acquisition when exposed to the 5Es Problem-Solving Model.

2.6.1 Gender and Science Process-Skills Acquisition

The significance of the interplay between gender and science process-skills acquisition comes to limelight when considered against the issue of enrolment, participation and achievement of male and female students in science, technical and mathematical subjects as well as the reasons behind the disparity. While some researchers such as Ige (2001), Aigbomian (2002), Raimi and Adeoye (2002) and Njoku (2004) reported that boys have higher levels of achievement than girls in science, technical and mathematical subjects, other researchers like Dahiru (2013) showed that sex played no significant role in performance in science, technology and mathematics. Dahiru (2013) however, raised the concern and worries that female performance and achievement in science, technology and mathematics is not fully encouraging. In the same vein, Nwaiwu and Audu (2005) observed that the number of female enrolment in tertiary education has increased at a slower rate than male enrolment and admitted that the gender gap in education is at the highest with male enrolment at least three times higher than that of female. More so, Aigbomian (2002) pointed out that girls and women tend to enrol in the humanities and are found to be under-represented in science, technology and mathematics disciplines where male dominate. This development according to Aigbomian (2002) has perhaps evolved from the fact that girls still have difficulty in understanding the physical sciences, notably, Physics. Nwagbo (2002) however reported that female science students' appreciation of the role of science is as much as their male counterparts but are lagging behind in knowledge-application and communication in science. Okeke (2001) attributed the gender disparity in enrolment and achievement in science and technology in tertiary institutions to gender stereotyping which assigns science as a male domain. Ogunboyede (2003) however is of the opinion that the development of sex differences in enrolment and achievement is facilitated and interwoven with the gradual process of socialization in many families, peer groups and age grades, religious institutions, schools as well as the mass media. Therefore, unless the females through acquisition of science process-skills are able to secure and retain jobs in science and technology fields in Nigeria, the gender inequality in enrolment, participation and achievement of male and female students in science, technical and mathematical subjects is unlikely to stop (Ibe, 2006).

Nonetheless, several empirical studies have been carried out to determine the effects of gender on science process-skills acquisition. Njoku (2002) examined the effects of mixed-sex and single-sex grouping strategies in coeducational classrooms on girls’ acquisition of science process-skills. The results revealed that girls in single-sex group scored significantly higher mean in science process-skills than girls in mixed-sex group. This was accounted for by the fact that in coeducational science classrooms, boys tend to dominate the learning activities especially during practical work. The findings further illustrated that although the girls in single-sex groups scored higher means in nearly all the selected science process-skills, the skill categories where the differences between these means are statistically significant seems to indicate the area where boys in mixed-sex group seriously dominate their girl-group members. In the area of manipulative skiils and conducting of experiments (skill A), controlling of extraneous variables (skill B) and mathematical computation skills (skill G) boys in the mixed-sex group must have dominated and reduced the participation of girls in their group, hence the girls could not sufficiently acquire these vital skills. The girls in mixed-sex group were however able to perform equally well like those in single-sex group in measuring out quantities (skill C), recording observations (skill D), working neatly and safely (skill E), and making inferences based on observations (skill F). This implies that girls in mixed-sex groups were not dominated in these activities during the practical work.

Ibe (2006) studied the effects of gender and teaching methods on science process-skills acquisition among senior secondary students and revealed from the findings that boys slightly performed better than girls but teaching methods had stronger effect than gender on levels of acquisition of science process-skills. From the findings, both male and female students had a high level of acquisition of science process-skills when exposed to the guided inquiry method which implies that girls can do equally well in science as boys when they are effectively and adequately exposed to science courses. However, the slight differences in scores in favour of males were attributed to gender stereotyped roles at home, socialization patterns and gender stereotyped occupation which stems from cultural impediments on women. Nwagbo and Chukelu (2011), in their studies on the effects of Biology practical activities on students' process skill acquisition, revealed that there was no significant difference between the mean science process-skill score of male and female students taught Biology using the practical approach.

Similarly, Usman, Ahmed and Tijjani (2014) investigated the effects of Biology practical activities on SS2 Students' process-skill acquisition from selected senior secondary schools in Sabon-Gari Local Government Area of Kaduna State. The results revealed that the practical activity method fostered the acquisition of science process skills in females more than in males though the difference was not significant. Omiko (2015) investigated the levels of possession of science process-skills (observation, experimentation, measurement, communication and inference) by final year NCE students of Biology, Chemistry, Physics and Integrated Sciences in colleges of education in south-eastern states of Nigeria. The results indicate that there was statistically significant difference between the mean ratings of the male and female final year NCE students in the levels of possession of science process-skills in favour of the males.

Guevara (2015) examined the effects of combining innovative approaches in teaching general Biology on the development of science process-skills among college non-science freshmen from a government-managed higher learning institution in the Philippines. The findings revealed that students' science process-skills differed across gender with male students having better science process-skills when exposed to innovative teaching approach. Eng et al. (2015) found no gender differences in the mastery of basic science process skills among primary school students. Ugwanyi (2015) found no significant gender differences in acquisition of a mixture of basic and integrated science process skills in Practical Chemistry. Similarly, Rabacal (2016) revealed that there is no significant difference on science process skills acquisition among undergraduate Biology students when grouped according to gender. Ghumdia (2016), Ongowo (2017) and Widdina, Rochintaniwati and Rusyati (2018) in their independent studies, indicated the existence of gender differences in the mastery of science process skills in favour of boys. However, Ong et al. (2012) and Zeidan and Jayosi (2015) in their separate studies, found gender differences in favour of female students with regard to knowledge of both basic and integrated science process skills.

It is therefore, one of the aims of this research to explore the effect of gender on the acquisition of science process-skills among secondary school Biology students in Zaria Education Zone, Nigeria.

2.6.2 Gender and Retention Ability of Students in Biology

Gender is an important factor in determining the cognitive abilities of individuals. Studies in Educational Psychology and Neurophysiology such as Vuoksimaa (2004) Ardila et al. (2011) and Abraham (2015) maintain that sex differences occur in cognitive functioning among individuals. These studies have reported female dominance in verbal abilities as well as male dominance in spatial and mathematical abilities. Therefore, retention being one of the cognitive functions could also be affected by sex differences among students. In line with the purpose of this study, the retention of learnt concepts among male and female students when taught using 5Es Instructional Model is of interest to the researcher.

Although several studies (Udogu&Njelita, 2010; Bunkure, 2012; Anil &Batdi, 2015; Ibrahim, 2015) have been conducted on the effect of 5Es Instructional Model on retention of learnt concepts among students, only a handful of these (Bunkure, 2012; Ibrahim, 2015) have actually examined the influence of gender on students' retention ability when exposed to the strategy. Bunkure (2012) examined the effect of a constructivist instructional strategy (based on the 5Es Model) on the academic achievement, retention and attitude to Physics among secondary school students of different ability levels in Kano State, Nigeria. The findings revealed that there is no significant difference in students' retention scores with reference to gender when exposed to the 5Es instructional model. Ibrahim (2015) investigated the impact of 5E Teaching Cycle on attitude, retention and performance in Genetics among Pre-NCE Biology students of different ability levels in North-West Zone, Nigeria. The results also show that male and female Pre-NCE Biology students exposed to the 5Es Teaching Cycle recorded no significant difference in their retention abilities.

Therefore, this study is focused on examining the effect of gender on retention ability of secondary school Biology students in Cell Physiology when exposed to 5Es Instructional Model in Zaria Education Zone, Kaduna State, Nigeria.

2.7 Overview of Similar Studies

A number of studies in literature like Pulat (2009), Udogu and Njelita (2010), Bunkure (2012), Shittu (2013), Ibrahim (2015), Supasorn (2015), Cakir (2017) among others, had investigated the general effectiveness of the 5Es Problem-Solving Model. Majority of the reviewed studies like Ibrahim (2015), Pulat (2009) and Supasorn (2015) centre on improving students' academic performance, attitude and conceptual understanding while a few like Umahaba (2016) and Cakir (2017) sought to advance the frontiers of knowledge in the areas of conceptual change, questioning style preferences, skill acquisition and knowledge retention among others. These studies cut across various disciplines in Science Education including Elementary Science, Integrated Science, Biology, Chemistry, Physics and Mathematics. The studies also cut across various educational levels including Elementary/Primary Schools, Junior Secondary Schools, Senior Secondary Schools; Colleges of Education and Universities. In terms of location, the reviewed studies cover places within Nigeria and abroad. The researcher also points out how the present study stands out from each reviewed study as well as what gap the present study seeks to fill as it applies to each literature reviewed.

Pulat (2009) investigated the Impact of 5Es Learning Cycle on 6th Grade Students' Achievement and Attitude towards Mathematics. The study was carried out in a public school with 28 sixth-grade elementary school students in Central Anatolia Region of Ankara, Turkey. One-group pretest, posttest, quasi-experimental design was used. Mathematics Achievement Test (MAT) and Mathematics Attitude Scale (MAS) were administered to collect data. The instruction was given by the researcher five hours per week in a 15-week period. The data were analyzed by using One-Way Repeated Measures Analysis of Variance (ANOVA) and a Paired-Samples t-test. It was found that there is a statistically significant change in Mathematics achievement of the students over three time periods (pre-intervention, post-intervention, and follow-up). There was however, a statistically significant decrease in mean score of attitude towards Mathematics from pre-intervention to post-intervention periods. The present study is similar to Pulat (2009) in that it explores the impact of 5Es Instructional Model on students' academic performance. However, it differs from it in so many ways. The present study differs from the aforementioned in two dependent variables which are Science Process-Skills Acquisition and Retention; in the subject area which is Biology; in the educational level which is SS2 or Grade 11 students; in the geographical location which is Zaria Education Zone, Kaduna State, Nigeria; in the sample size which is 110 students; in instruments used for data collection which are SPSAT and CPPT; and in the statistical tool employed for data analysis which is the Independent Samples t-test. Unlike Pulat (2009) that employed a quasi-experimental design involving one group and administered treatment for 5 hours per week for 15 weeks, the present study adopts a quasi-experimental design involving two groups and administered treatment for 80 minutes per week for 6 weeks. It is worthy of note therefore, that the present study would fill the gap in science process-skills acquisition and retention as well as gender-related issues in Cell Physiology concept among SS2

Biology students in Zaria Education Zone, Kaduna State, Nigeria that was not captured in the former study.

Ceylan and Geban (2009) compared the effectiveness of 5E Learning Cycle Model Based Instruction and traditionally designed Chemistry instruction on 10th Grade students' understanding of State of Matter and Solubility concepts. The study sample comprises 119 tenth-grade Chemistry students from an Anatolian High School in Ankara, Turkey. The study employed a quasi-experimental, pre-test, post-test, control group design involving two groups. Students in the experimental group were instructed based on 5E Learning Cycle Model while students in control group were taught with traditional method. The instruments used for data collection were State of Matter and Solubility Concept Test (SMSCI) and Science Process Skills Test (SPST). Univariate Analysis of Covariance (ANCOVA) was employed in data analysis. The results showed a significant difference between the posttest mean scores of the students in the experimental and control groups with respect to understanding of State of Matter and Solubility concepts when science process skills was controlled as a covariate. In comparison to Ceylan and Geban (2009), the present study compares the effectiveness of 5Es Instructional Model and Traditional Lecture Method on secondary school students' academic performance. The present study is also similar to the above mentioned in the experimental design, duration and mode of treatment administration. In contrast however, the present study differs from the aforementioned in two dependent variables (i.e. Science Process-Skills Acquisition and Retention); in the subject area (i.e. Biology); in the class of students (i.e. SS2 or 11th Grade); in the concept taught (i.e. Cell Physiology); in the geographical location (i.e. Zaria Education Zone, Kaduna State, Nigeria); in the sample size (i.e. n = 110); in the instrumentation (i.e. SPSAT and CPPT); and in the tool for data analysis (i.e. Independent Samples t-test). In Ceylan and Geban (2009), science process-skills was controlled as a covariate while in the present study science process-skills is to be treated as a dependent variable whose acquisition would be measured among the research subjects. Therefore that the present study would fill the gap in science process-skills acquisition and retention as well as gender-related issues in Cell Physiology concept among SS2 Biology students in Zaria Education Zone, Kaduna State, Nigeria.

Udogu and Njelita (2010) investigated the Effect of Constructivist-Based 5Es Instructional Model on Students' Conceptual Change and Retention on some Difficult Concepts in Chemistry in Anambra State, Nigeria. Quasi experimental, non-equivalent control group design involving 2 intact classes was used. The target population was all SS2 Chemistry students in the study area and the sample size was 170 students from four secondary schools purposefully selected in Idemili South Local Government Area of Anambra State. A Teacher Made Chemistry Achievement

Test (TMCAT) was used as the instrument drawn from some Chemistry concepts namely; Electrolysis, Redox Reaction, Calculations involving Mass and Chemical Equilibrium. Analysis of Co-variance (ANCOVA) was used to test the null hypothesis at $P \leq 0.05$ level of significance. From the findings, it was observed that the experimental group subjects which received instruction based on the 5Es Model, performed significantly better as well as retained knowledge more than the control group subjects that received instruction based on the Lecture Method. This was an indication that the 5Es Model is effective in enhancing meaningful learning, leading to conceptual change among Chemistry students. The above study is similar to the present one in that it investigates the effect of 5Es Instructional Model on Retention of learnt concepts among SS2 students. Both studies are also similar in experimental design, duration of treatment and mode of treatment administration. Unlike the Udogu and Njelita (2010) however, the present study differs in two dependent variables (i.e. Science Process-Skills Acquisition and Academic Performance); in subject area (i.e. Biology); concept (i.e. Cell Physiology); location (i.e. Zaria Education Zone, Kaduna State, Nigeria); sample size (i.e. n = 110); sampling technique (i.e. Simple Random Sampling); and instrumentation (i.e. SPSAT and CPPT) and in the tool employed for data analysis (i.e. Independent Samples t-test). The present study would therefore, address the gaps in science process-skills acquisition and academic performance as well as gender-related issues in Cell Physiology concept among Secondary School Biology students in Zaria Education Zone, Kaduna State, Nigeria.

Ozlem and Jale (2010) examined the effectiveness of 5Es Learning Cycle Instruction on academic achievement of 11th Grade Biology Students in Human Circulatory System concept in Turkey. The study employed a quasi-experimental, pretest, posttest, control group design. Two teachers and four classes with a total of 60 eleventh grade students participated in the study. One class for each teacher was assigned as experimental group and treated with 5Es Learning Cycle Instruction and the other as control group and treated with traditional instruction. The Human Circulatory System Achievement Test (HCSAT) was used both as pretest and post-test to assess students' achievement on Human Circulatory System concepts. Analysis of Variance (ANOVA) was used for data analysis and the results revealed that 5Es Learning Cycle Instruction significantly improved students' achievement in Human Circulatory System compared to traditional instruction. The present research is similar to the Ozlem and Jale (2010) in that it examines the effect of 5Es Instructional Model on SS2 (11th Grade) Biology students' academic performance. It is also similar in terms of the experimental design adopted. However, the present study differs in two dependent variables (i.e. Science Process-Skills Acquisition and Retention); in the concept taught (i.e. Cell

Physiology); location (i.e. Zaria Education Zone, Kaduna State, Nigeria); sample size (i.e. n = 110); instrumentation (i.e. SPSAT and CPPT); and in the statistical tool for data analysis (i.e. Independent Samples t-test). The present study also differs from the aforementioned in that it used two classes instead of four and one teacher (the researcher) instead of two (school teachers). The present study shall therefore fill the gaps of science process-skills acquisition and retention as well as gender-related issues in Cell Physiology concept among SS2 Biology students in Zaria Education Zone, Kaduna State, Nigeria, that was not captured in the previous study.

Nwagbo and Chukelu (2011) investigated the effects of Biology practical activities on secondary school students' process skills acquisition in Abuja Municipal Area Council, Nigeria. The design of the study was Quasi-Experimental, specifically the Pretest-Posttest, Non-Equivalent Groups Design. A sample of 111 SS1 Biology students randomly drawn from two co-educational schools is used for the study. The instrument used for data collection was the Science Process Skill Acquisition Test (SPSAT) developed by the researchers. Data collected were analyzed using mean, standard deviation and Analysis of covariance (ANCOVA) at 0.05 level of significance. The results revealed that Practical Activity Method was more effective in fostering students' acquisition of science process skills than the Lecture Method. The findings also show that male and female students do not differ in their science process-skills acquisition, and there was no interaction between method and gender on students' process skill acquisition. The present research is similar to the Nwagbo and Chukelu (2011) in its examination of Science Process-Skills as a dependent variable. It is also similar in the subject area and experimental design adopted. However, the present study differs in two dependent variables (i.e. Academic Performance and Retention); in the concept taught (i.e. Cell Physiology); instrumentation (i.e. CPPT) location (i.e. Zaria Education Zone, Kaduna State, Nigeria); sample size (i.e. n = 110); and in the statistical tool for data analysis (i.e. Independent Samples t-test). The present study also differs from the aforementioned in the instrument used for assessing students' science process-skills. The present study shall therefore fill the gaps of academic performance and retention in Cell Physiology among SS2 Biology students in Zaria Education Zone, Kaduna State, Nigeria, that was not captured in the previous study.

Bunkure (2012) conducted a study on the effect of Constructivist-Based Instructional Approach based on 5Es Learning Model on the Academic Achievement, Retention and Attitude to Physics among Secondary School Students of Varied Ability Levels in Kano State, Nigeria. The study was quasi-experimental, employing the pretest-posttest control group design. A simple random sampling technique was used to select 4 schools out of 7

Science Senior Secondary Schools in Kano State. Sample of 160 out of 1,559 SS II Physics students were used for the study. Physics Achievement Test (PAT) and Physics Attitude Questionnaire (PAQ) were used to collect data. Six null hypotheses were tested at $p \leq 0.05$ level significance using t-test, one-way Analysis of Variance (ANOVA), and Mann Whitney U test statistics. The findings revealed that students exposed to Constructivist Instructional Strategy achieved more, retained the learnt concepts better and developed more positive attitude to Physics than their counterparts exposed to conventional method of teaching. The findings also revealed that there is no significant difference in students' achievement with reference to gender and the strategy is suitable for students of varied ability levels. The present study compares with Bunkure (2012) in that it examines the impact of 5Es Instructional Model on SS2 students' academic performance and retention as well as in its address of gender issues. It is also similar in the experimental design and sampling technique. In contrast to the aforementioned study, the present study differs in one dependent variable (i.e. Science Process Skills Acquisition); in the subject area (i.e. Biology); location (i.e. Zaria Education Zone, Kaduna State, Nigeria); population, sample size, instrumentation and the statistical tool employed for data analysis (i.e. Independent Samples t-test). The present study would therefore, address the gap of science process-skills acquisition in Cell Physiology concept among secondary school Biology students in Zaria Education Zone, Kaduna State, Nigeria, that was not addressed by the abovementioned study.

Shittu (2013) investigated the Effects of Guided-Inquiry Strategy using 5Es Learning Cycle on Learning Outcomes of Low Achieving Secondary School Physics Students in Kaduna Metropolis, Kaduna State, Nigeria. The population consisted of 1,714 SS2 students from which 91 low achieving students were randomly selected as sample for the study. Quasi-experimental design involving pretest and posttest was adopted for the study. The experimental group was taught by Guided-Inquiry based on 5E Model while the control group was taught using Lecture Method for six weeks. t-test and Wilcoxon statistics were used to analyse data and the results show that low achieving students taught Physics concepts using the Inquiry Method achieved significantly higher than those taught using Lecture Method. The attitude of the experimental group subjects was also greatly improved. The findings also revealed that Guided-Inquiry based on 5E Model favoured both male and female low achieving Physics students. The present study focuses however, on the impact of the 5Es Instructional Model on acquisition of science process-skills, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone of Kaduna State, Nigeria.

Yadav and Mishra (2013) examined the effects of Laboratory Approach based on the 7E Learning Cycle Model on university students' development of science process skills and conceptual achievement. The sample consisted of 81 freshman university students who were taking the General Physics Laboratory I course. The study was quasi-experimental, adopting the pretest-posttest, non-equivalent groups design. Instruments used for data collection include Science Process Skills Test (SPST) and Force Concept Inventory (FCI). Data collected were analysed using Mean, Standard Deviation and Independent Samples t-test statistics. The findings revealed that the achievement of students exposed to Laboratory Approach was significantly higher than those taught using Traditional Approach. The development of process skills was also significantly higher among students who were taught by Laboratory Approach. The present study focuses however, on the impact of the 5Es Instructional Model on acquisition of science process-skills, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone of Kaduna State, Nigeria.

Njoroge, Changeiywo, and Ndirangu (2014) investigated the effects of inquiry-based teaching approach using 5Es Learning Cycle on secondary school students' performance and motivation in Physics in Nyeri County, Kenya. The study adopted a Solomon-Four Non-equivalent Group Design. Stratified random sampling technique was used to select four boys' and four girls' county secondary schools in Nyeri, County. The four schools in each category were assigned to treatment and control groups by simple random sampling technique. Each group had one boys' and one girls' county secondary school. Each school provided one form two class for the study and a total of 370 students were involved. Students in all the groups were taught the same physics content but the experimental groups were taught using Inquiry-Based Teaching (IBT) approach while the control groups were taught through Regular Teaching Methods (RTM) such as Lecture Methodand teacher demonstrations. The experimental group I and the control group II were pre-tested prior to the implementation of the IBT treatment. After four weeks, all the four groups were post-tested using the Students' Physics Achievement Test (SPAT). The instruments were scored and data was analyzed using t-test, one way ANOVA and ANCOVA at a significance level of 0.05. The findings of the study showed that Inquiry-Based Teaching (IBT) approach resulted into higher students' scores in achievement in physics. It is however, the aim of this research to the determine of the extent to which the 5Es Instructional Model would impact science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria, Nigeria.

In a study carried out by Ibrahim (2015), the impact of 5Es teaching cycle was examined on attitude, retention and performance in genetics among pre-NCE Biology students of different ability levels in North-West Zone, Nigeria. The research design was Quasi-experimental and control group design employing pretest and posttest and post-posttest. The population was 2,231 pre-NCE Biology students of Colleges of Education in the North-Western Nigeria which covers Katsina, Kaduna, Jigawa, Kebbi, Kano, Sokoto and Zamfara. The sample comprised of 110 students selected from two out of the eleven coeducational colleges of education that constitute the population of the study. Two instruments, namely: Genetics Academic Performance Test (GAPT) and Students Attitude to Genetics Questionnaire (SAGQ) were used for data collection. Pretest was administered to the subjects before they were exposed to the treatment and the ability grouping was carried out by categorizing the subjects into high, average and low groups based on their pretest scores. The experimental group was exposed to 5Es teaching cycle while the control group was exposed to Lecture Method. The posttest was given to both groups to determine the effects of the treatments and post-posttest was administered after two weeks to determine retention. Data obtained were analysed using Mean scores, Two-way Analysis of Variance (ANOVA) and Kruscal Wallis test statistics at $P \leq 0.05$ level of significance. The findings of the study showed that pre-NCE Biology students exposed to 5Es teaching cycle in the teaching and learning of genetics concepts in all the ability levels had higher mean performance scores and also retained more than those in the control group exposed to Lecture Method of instruction. Males and females in all the ability groups exposed to 5Es teaching cycle performed equally well and had also no difference in their retention abilities. The attitude of the experimental group also improved significantly in all the three ability levels. The present study unlike Ibrahim (2015) examines the impact of 5Es Instructional Model on science process-skills acquisition, performance and retention in cell physiology among secondary school students in Zaria Education Zone of Kaduna State, Nigeria.

Hirca (2015) developed and suggested a proposal for primary school teachers (PSTs) in Turkey to teach science and science process-skills without focusing on "structure" of experiments based on constructivist 5Es model. The study was due to Hirca's observation that a large number of prospective primary teachers (PPTs), by virtue of their background, feel anxious about doing science experiments. Some "extended" simple science experiment (ESSE) samples were implemented on 39 PPTs according to the proposal. Then 39 PPTs were allowed to design and to conduct several ESSE. Finally, they assessed their ESSE experiences. They concluded that ESSE is not only easy and enjoyable to engage in science but also useful for teaching and learning science concepts and science process-skills. The present study differs from Hirca (2015) by investigating the impact of 5Es instructional model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone of Kaduna State, Nigeria.

Supasorn (2015) studied Grade 12 Students' Conceptual Understanding and Mental Models of Galvanic Cells before and after Learning by using Small-Scale Experiments in Conjunction with a Model Kit. The small-scale experiments were implemented based on the 5E Inquiry Learning Approach to enhance students' conceptual understanding of Electrochemistry. The treatment tools consist of four small-scale experiments and the galvanic cell model kit. The data collection tools include a Conceptual Test of Electrochemistry and the Mental Model Drawing of a Galvanic Cell. A sample of 34 grade 12 students participated in the 5E learning activities for a total of 10 hours. Paired samples *T*-test was used for data analysis at the 0.05 significance level. Results revealed that the mean score of the post-conceptual test was statistically higher than that of the pre-conceptual test. In addition, the mean score of the post-mental models was statistically higher than that of the pre-mental models. Prior to intervention, most students were in the categories of less correct conceptions – Partial Understanding with Specific Misunderstanding (PMU) to No Understanding (NU). However, after the intervention, they moved to the categories of more correct conceptions – Partial Understanding (PU) to Sound Understanding (SU). This indicates that the intervention enhanced students' conceptual understanding of electrochemistry and mental models of galvanic cells. The present study differs from the abovementioned, as it examines the impact of 5Es Instructional Model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone of Kaduna State, Nigeria.

Anil and Batdi (2015) undertook a Comparative Meta-Analysis of 5E and Traditional Approaches in Turkey. The aim of the study was to compare the 5E Learning Model with traditional learning methods in terms of their effect on students' academic achievement, retention and attitude scores. In this context, the meta-analytic method known as the 'analysis of analyses' was used and a review undertaken of the studies and theses (N=14) executed in Turkey over the period 2008-2014 on the 5E model. The goal of the review was to determine the efficacy of the 5E Instructional Model in terms of academic achievement, retention and attitude scores. The treatment effect method was used in the data analysis and the Comprehensive Meta-Analysis (CMA) statistical program, the MetaWin and Microsoft Excel 2010 Office programs were employed for the effect size calculation. The effect size values resulting from the analysis were interpreted according to Cohen classification (1992). When academic achievement, retention and attitude scores in the studies implementing the 5E instructional model were calculated according to the random effects model, effect size values were found to be ESacademic achievement=1,132, ESretention: 1,417 and ESattitude=0,552, respectively. In regard to academic achievement and retention, it can be inferred that these effect sizes of the 5E Learning Cycle were large and medium with respect to attitude, while both were positive and significant. It can therefore be said that the 5E model has a positive effect on academic achievement, retention and attitude scores. The present study however investigates the impact of 5Es Instructional Model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone of Kaduna State, Nigeria.

Zeidan and Jayosi (2015) studied the relationship between Palestinian secondary school students' knowledge level of science process skills and their attitudes toward science as well as the effect of gender and residence of these students on their knowledge level of science process skills and attitudes toward science. The design was correlational. The population consisted of all secondary grade students in the district of Tulkarm, Palestine. A sample 159 students (72 males and 87 females) was selected from the city and villages by stratified random sampling. The study used an 18-question Science Process Skills Test (SPST) and a 25-item Attitudes toward Science Questionnaire (ATSQ). Pearson Product Moment Correlation and One-Way ANOVA were used to analyse data collected. The results indicate that the association between knowledge level of science process skills and attitudes toward science were significant. The findings also reveal that there were significant differences in science process skills due to gender favouring females; and due to residence favouring students from the villages. However, there were no significant differences in attitudes toward science due to the gender and residence. The present study differs from the aforementioned as it examines the impact of 5Es Instructional Model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone of Kaduna State, Nigeria.

Cetin-Dindar and Geban (2016) investigated the effect of 5E Learning Cycle Model Oriented Instruction (LCMI) on 11th-grade students' conceptual understanding of acids and bases concepts and student motivation to learn chemistry. The study, which lasted for 7 weeks, involved two groups: An experimental group (LCMI) and a control group (the traditional teacher-centered instruction [TTCI]). Based on multivariate analysis of covariance results, the LCMI students outperformed the TTCI students in terms of conceptual understanding about acids and bases. Similarly, the students from the experimental group scored higher motivation and this difference was found to be statistically significant. These findings demonstrated that instruction based on learning cycle model provide students a deeper conceptual understanding, foster high-order thinking, engage them in the learning process, and influence their motivation to learn by increasing the relevance of school chemistry to their daily lives. The present study differs from the aforementioned as it investigates the impact of 5Es Instructional Model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone of Kaduna State, Nigeria.

Umahaba (2016) investigated the impact of 5Es Learning Cycle Model on questioning style preference and academic performance among senior secondary school II Chemistry students in Katsina Metropolis, Nigeria. A Quasi-experimental, pretest-posttest research design, featuring two groups was adopted. The sample consisted of 164 students selected from two secondary schools in Katsina Metropolis which was drawn from a population of 753 students from 10 schools. The Instrument used was Chemistry Performance Test (CPT). The data collected were analyzed using t-test statistic, ANOVA, ANCOVA and Scheffe's test at significance level of $P \leq 0.05$. The results indicated that the experimental group which was exposed to the 5Es Learning Cycle Model performed significantly better than the control group which was taught using the Lecture Method. The model was also found to have enhanced significantly, the experimental group's ability to answer more difficult questions compared to the control group. The treatment had no significant effect on students' performance based on gender and there is no significant difference between male and female students' cognitive questioning preference when exposed to the 5Es Learning Model. The present research differs from Umahaba (2016) as it investigates the impact of 5Es Instructional Model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone of Kaduna State, Nigeria.

Ghumdia (2016) investigated the effects of inquiry-based teaching strategy on secondary school biology students' science process skill acquisition in Biu Educational Zone, Borno State, Nigeria. The study design was quasi-experimental, specifically the Pretest-Posttest, Non-Equivalent Groups Design. A sample of 160 SS II Biology students randomly drawn from four coeducational schools was used for the study. The instrument used for data collection was Biology Students' Process Skill Acquisition Test (BSPSAT). Data collected were analyzed using Mean, Standard Deviation and Analysis of Covariance (ANCOVA) at 0.05 level of significance. The results revealed that Inquiry-Based Method significantly fostered students' acquisition of science process skills than Lecture Method. There was significant effect of treatment on students' acquisition of science process skills but no interaction between method and gender on students' process skill acquisition. The present study however differs from the aforementioned as it investigates the impact of 5Es Instructional Model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone of Kaduna State, Nigeria.

Jack (2017) investigated the effect of Learning Cycle Approach on secondary School Students' Achievement and Attitude towards Chemistry in North-Eastern Nigeria. The study adopted a Pretest-Posttest, Non-Randomized Groups, Quasi-Experimental Research Design. The sample of the study comprised 120 SS 2 students from four mixed Senior Secondary Schools randomly drawn from the population. The instruments used in collecting data were Chemistry Achievement Test (CAT) and Chemistry Attitude Scale (CAS). The data were analyzed using Mean, Standard Deviation and ANCOVA statistics. The findings indicated that students taught with Learning Cycle Approach significantly achieved better in Chemistry than those taught with Lecture Method. A non-significant difference existed in academic achievement between students with positive and negative attitudes after treatment. The present study however differs from Jack (2017) as it investigates the impact of 5Es Instructional Model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone of Kaduna State, Nigeria.

Cakir (2017) undertook a Meta-Analysis Study on the Effect of 5E Learning Model on Academic Achievement, Attitude and Science Process-Skills in Turkey. In this evaluative research, all the Master's, doctoral theses and articles in Turkish and English languages which were carried out in Turkey between 2006 and 2016 and which are suitable for the research problem were scanned and included in the scope of the study. In order to limit studies and conduct meta-analysis in this context, studies had to be planned with semi-experimental design with experiment and control groups; there had to be quantitative data such as mean, standard deviation, and sample size and they had to be applied only in science courses. The data obtained from the articles and theses were meta-analyzed and it was determined that the 5E learning model had an effect on the students' academic achievement, attitude towards science and science process skills implying that the effect of the method applied for each dependent variable was found to favour the experimental group. The present study differs from Cakir (2017) as it investigates the impact of 5Es Instructional Model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone of Kaduna State, Nigeria.

Ongowo (2017) investigated secondary school students' mastery of Integrated Science Process Skills (ISPS) among co-educational schools and the influence of grade level, gender and school location in Siaya County, Kenya. The study used a causal-comparative design with purposive sampling technique. A 30-item Test of Integrated Science Process Skill (TISPS) developed by Kazeni (2005) was administered. The instrument assesses the skills of controlling variables, defining operationally, formulating hypotheses, experimenting and interpreting data. The instrument was administered to 429 students, 117 of which are in grade 9, 108 in grade 10, 101 in grade 11 and 103 in grade 12. The sample was drawn from one urban co-educational school (n = 215) and one rural co-educational school (n = 214). The data were analyzed by grade level using One-Way ANOVA and by gender and school location using an independent samples t-test. The findings indicated moderate mastery of ISPS and statistically significant grade level differences between grades 9 and 10, 10 and 11, 11 and 12, 9 and 11, 9 and 12, and 10 and 12; gender differences in favour of boys and school location differences in favour of urban school students in mastery of ISPS. The researcher concluded that mastery of ISPS increases with grade level; boys have a higher mastery of ISPS than girls; and the urban school has a higher mastery of ISPS than the rural school. The present study differs however, from Ongowo (2017) as it investigates the impact of 5Es Instructional Model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone of Kaduna State, Nigeria.

2.8 Implications of the Literature Reviewed on the Present Study

The literature reviewed clearly indicate the effectiveness of the 5Es Problem-Solving Model in enhancing performance, attitude, conceptual change, motivation, retention, cognitive questioning style preferences and science process-skills acquisition among a variety of student levels and across different subject areas in the sciences as well as different locations in the world. Studies that examined the 5Es Instructional Model in relation to academic performance include Pulat (2009), Udogu and Njelita (2010), Ozlem and Jale (2010), Bunkure (2012), Shittu (2013), Njoroge, Changeiywo, and Ndirangu (2014), Ibrahim (2015), Anil and Batdi (2015), Umahaba (2016), Cakir (2017) and Jack (2017). These studies generally point to the efficacy of 5Es Instructional Model in enhancing academic performance among students in comparison to Traditional Lecture Method. Studies on the 5Es Instructional Model that examined the acquisition of science process-skills among students include Hirca (2015) and Cakir (2017) while those that explored students' retention include Udogu and Njelita (2010), Bunkure (2012), Ibrahim (2015) and Anil and Batdi (2015). These studies also indicate that the use 5Es Problem-Solving Model generally fosters the acquisition of science process-skills and retention among students in comparison to Conventional Method.

The literature reviewed has substantiated evidence on the efficacy of 5Es Instructional Model on the academic performance of students. However, considerable empirical evidence is lacking in the aspects of science process-skills acquisition and retention among senior secondary school students in Nigeria. It is also evident from the literature reviewed that most studies on the 5Es Instructional Model were carried out abroad (especially in Turkey) while only a few were undertaken in Nigeria. Based on these fundamental observations, the present study seeks to contribute to the knowledge-base on the impact of 5Es Problem-Solving Model on science process-skills acquisition performance and retention among secondary school Biology students in Nigeria, with focus on Zaria Education Zone, Kaduna State, Nigeria.

In addition, the literature reviewed have shown that only a limited number of studies on the 5Es Instructional Model have been undertaken in Biology and those were centered on concepts other than Cell Physiology. This concept has been proven to be a significant bottleneck to students' achievement in SSCE Biology. More so, not many studies have been undertaken to address secondary school Biology students' poor science process-skills acquisition, academic performance and retention in the difficult areas of Cell Physiology like Diffusion, Osmosis, Active Transport, Endocytosis, Exocytosis, Cellular Respiration, Photosynthesis and Cell Division. The present study however addresses this gap in literature as well as contributes to the pool of empirical evidence on the impact of 5Es Problem-Solving Model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone, Kaduna State, Nigeria.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This study investigates the impact of 5Es Problem-Solving Instructional Model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone, Kaduna State, Nigeria. In this chapter, the procedures employed in conducting the research are discussed under the following sub-headings:

3.2 Research Design

3.3 Population of the Study

3.4 Sample and Sampling Techniques

3.5 Instrumentation

3.5.1 Validity of the Instruments

3.5.2 Concept Selected for the Study

3.6 Pilot Testing

3.6.1 Reliability of the Instruments

3.6.2 Item Analysis

3.7 Administration of the Treatment

3.7.1 Treatment of the Experimental Group

3.7.2 Teaching the Control Group

3.8 Data Collection Procedure

3.9 Procedure for Data Analysis

3.2 Research Design

The design of this study is Quasi-Experimental, involving specifically, the Pretest-Posttest,Non-Equivalent-Groups Design. According to Best and Kahn (2014), a Quasi-Experimental Design is often used in classroom experiments and does not involve the random assignment of participants into treatment groups. This study involved two groups: an experimental and a control group. Intact classes were used in order not to disrupt school organization. Pre-test (O_1) was administered to both groups to establish their equivalence as well as measure the students' initial level of skill acquisition and academic performance in Cell Physiology. The Experimental Group (EG) was taught the concept of Cell Physiology using 5Es Instructional Model(X_1) while the Control Group (CG) was taught the same conceptusing ConventionalMethod(X_0) for six (6) weeks each. After the treatment, post-test (O_2) was administered to both groups to determine the effect of the two instructional strategies on students' science process-skills acquisition and academic performance in Cell Physiology. Post-Posttest (O_3) was administered two weeks later to determine students' retention ability. The design of the study is shown in Figure 3.1:

EG	→	O_1 (SPS; AP)	→	X_1	→	O_2 (SPS; AP)	→	O_3
CG	→	O_1 (SPS; AP)	→	X_0	→	O_2 (SPS; AP)	→	O_3

Fig 3.1: Research Design

KEY

EG: Experimental Group　　**CG:** Control Group

O_1: Pre-test　　**O_2:** Posttest

O_3: Post-Posttest　　**X_1:** 5Es Problem-Solving Instructional Model

X_0: Conventional Method　　**SPS:** Science Process-Skills Acquisition

AP: Academic Performance

3.3 Population of the Study

The population for this study comprised all public Senior Secondary School II (SS2) Biology Students in Zaria Education Zone of Kaduna State, Nigeria. There are 7,807 SS2 students (3,918 males and 3,889 females) offering Biology in the zone. The Zaria Education Zone also has a total of 30 public Senior Secondary Schools made up of 20 co-educational schools, 5 purely male and 5 purely female schools. The schools offer Biology as a core science subject. Details of the population are presented in Table 3.1.

Table 3.1: Population of the Study

S/N	Name of Schools	Type	Number of SS II Students		
			Male	Female	Total
1.	GSS Muchia (Senior)	Co-educ.	196	263	459
2.	GSS Aminu (Senior)	Co-educ.	128	103	231
3.	GSS Magajiya	Co-educ.	198	87	285
4.	GSS Kaura	Co-educ.	205	138	343
5.	GSS TudunJukun	Co-educ.	103	161	264
6.	GSS KofanKuyanbana	Co-educ.	175	300	475
7.	SIASS Karau Karau (A)	Co-educ.	33	10	43
8.	GSS Dakace	Co-educ.	101	77	178
9.	GSS Kugu	Co-educ.	71	13	84
10.	GSS Tudun Saibu (Snr)	Co-educ.	85	38	123
11.	GSS Likoro	Co-educ.	34	20	54
12.	GSS Richifa	Co-educ.	27	01	28
13.	SIASS Karau Karau (B)	Co-educ.	120	144	264
14.	GSS Awai	Co-educ.	26	02	28
15.	GSS Yakasai	Co-educ.	41	15	56
16.	GSS Dinya	Co-educ	42	04	46
17.	GSS Gyallesu	Co-educ.	202	116	318
18.	GSS Bogari	Co-	28	01	29

		educ.			
19.	GSS KofanJatau	Co-educ.	102	207	309
20.	GSS Kofan Doka	Co-educ.	195	154	349
21.	Alhudahuda College, Zaria	Male	675	-	675
22.	Barewa College, Zaria	Male	428	-	428
23.	GSS Zaria	Male	230	-	230
24.	GSS Chindit Barracks (Snr)	Male	283	-	283
25.	SSS Kufena	Male	190	-	190
26.	GGSS Dogon Bauchi	Female	-	532	532
27.	GGSS KofanGayan	Female	-	487	487
28.	GGSS Fada	Female	-	484	484
29.	GGSS Chindit Barracks (Snr)	Female	-	262	262
30.	GGSS Zaria (WTC)	Female	-	270	270
	TOTAL		**3,918**	**3,889**	**7,807**

Source: Ministry of Education, Zonal Education Office, Zaria, Kaduna State (2019).

3.4 Sample and Sampling Technique

The sample for this study comprised 110 SS2 Biology students (75 males and 35 females) from 2 randomly selected public co-educational Senior Secondary Schools in Zaria Education Zone of Kaduna State, Nigeria. Simple random sampling with replacement through the Lucky Dip Method was used to select four (4) schools from the twenty (20) co-educational Senior Secondary Schools in the study area. According to Anikweze (2013), this technique ensures that each element in a population has equal chance of being selected and the resulting sample is representative of the population. The four schools selected were Government Secondary School Dakace, Government Secondary School Likoro, Government Secondary School Kugu and Government Secondary School

Yakasai. Pre-test was administered to the SS2 Biology students in each of the four schools randomly selected to determine their equivalence in terms of process-skills acquisition and academic performance in Cell Physiology. This was achieved by subjecting the results obtained from the pre-test to One-Way Analysis of Variance (ANOVA) and Scheffe's post-hoc test. One-Way ANOVA was used to determine the existence of any significant difference in the four schools while the Scheffe's post-hoc test was used to separate the schools and figure out which schools were significantly or not significantly different. Two schools (i.e. G.S.S. Likoro and G.S.S. Yakasai) were statistically homogeneous and were therefore used for the study. The Tables for ANOVA and Scheffe's Test are presented in Appendix J.

One school was randomly assigned the experimental group (School A) and the other as the control group (School B) by simple coin flipping. There are 54 students (34 males and 20 females) in the experimental group and 56 students (41 males and 15 females) in the control group. The optimum sample size required for each participating group in an experimental research as recommended by Coolican (1999) and Gall, Borg and Gall (2003) is 30 respondents. This compared very well with the sample size employed in this study. Mugenda and Mugenda (2003) recommended a class size of at least 30 students in each group in a quasi-experimental research. The sample size for this study also conforms to the Central

Limit Theory which, according to Sambo (2008), recommends a minimum of 30 students per group in a study of this nature. The details of the sample for this study are presented in Table 3.2.

Table 3.2: Sample of the Study.

S/N	School Name	Group	Male	Female	Total
1	School A	Experimental	34	20	54
2	School B	Control	41	15	56
	Total		**75**	**35**	**110**

3.5 Instrumentation

Three instruments were employed in this study. Two were used for data collection while one was used as an instructional package for the treatment group. The instruments are:

1. Science Process Skills Acquisition Test (SPSAT);
2. Cell Physiology Performance Test (CPPT);
3. 5Es Instructional Package (5-EIP).

1. Science Process-Skill Acquisition Test (SPSAT)

SPSAT consists of 30 alternative-to-practical items cutting across a variety of question types including short-answer, item-completion, multiple choice, graphing and drawing. The test was adapted from Ajagun's (1998) Test of Process Skills in Biology. SPSAT was meant to measure the students' acquisition of the six (6) basic science process-skills which include observation, measurement, classification, communication, inference and prediction. Details of items contained in this instrument are presented in Appendix A and the marking scheme in Appendix B.Table 3.3shows the item specification for SPSAT.

Table 3.3: Item Specification for SPSAT.

S/No.	Process-Skills	Items	Total	Weight
1.	Observation	1, 2, 6, 9, 18, 22, 25, 26, 28.	9	30.0%
2.	Measurement	5, 10, 14, 19.	4	13.3%
3.	Classification	3, 7, 30.	3	10.0%
4.	Communication	8, 12, 15, 20, 21.	5	16.7%
5.	Inference	13, 16, 23, 27, 29.	5	16.7%
6.	Prediction	4, 11, 17, 24.	4	13.3%
	Total		**30**	**100%**

Source: Adapted fromAjagun (1998).

Table 3.3 indicates that a total of 30 questions are contained in SPSAT covering the six basic science process-skills. 9 questions (30%) test the skill of "observation"; 4 questions (13.3%) test the skill of "measurement"; 3 questions (10%) test the skill of "classification"; 5 questions (16.7%) test the skill of "communication"; 5 questions (16.7%) test the skill of "inference" and 4 questions (13.3%) test the skill of "prediction".

2. Cell Physiology Performance Test (CPPT)

The instrument consists of 40 multiple choice items meant to assess the performance of students in Cell Physiology concepts. The performance test was adapted from past WASSCE Biology questions from 1998-2018. The questions were based on the contents of the topics under Cell

Physiologyas stipulated in the Senior Secondary Biology curriculum. The multiple-choice item format was used because it allows for a wider coverage of the contents and is normally free of bias in marking. The itemsconsisted of four alternatives (A-D), one of which is the correct answer and the others, distracters. The test items reflected the six cognitive levels based on Bloom's (1975) taxonomy. Details of items contained in CPPT are presented in Appendix C and the marking scheme in Appendix D. The number of questions, weight and item specification for each topic ispresented in Table 3.4.

Table 3.4: Table of Specification for CPPT based on Bloom's Taxonomy

Topics	KNL (32.5%)	CMP (17.5%)	APL (20%)	ANL (12.5%)	SYN (7.5%)	EVL (10%)	TOTAL	Weight (100%)
1. Diffusion and its applications in living and non-living systems.	2 (1,2)	1 (3)	1 (4)	0 (-)	1 (5)	1 (6)	**6**	**15 %**
2. Osmosis and its applications in living and non-living systems.	2 (7,8)	1 (9)	1 (10)	1 (11)	0 (-)	1 (12)	**6**	**15%**
3. Active	3	1	1	1	1	0	**7**	**17.5%**

Transport, Endocytosis and Exocytosis and their applications.	(13,14,15)	(16)	(17)	(18)	(19)	(-)		
4. Cellular Respiration (Catabolism).	2 (20,21)	1 (22)	1 (23)	1 (24)	1 (25)	1 (26)	**7**	**17.5%**
5. Photosynthesis (Anabolism).	2 (27,28)	1 (29)	2 (30,31)	1 (32)	0 (-)	1 (33)	**7**	**17.5%**
6. Mitosis and Meiosis and their applications.	2 (34,35)	2 (36,37)	2 (38,39)	1 (40)	0 (-)	0 (-)	**7**	**17.5%**
Total	**13**	**7**	**8**	**5**	**3**	**4**	**40**	**100%**

Source: Researcher (2018).

Table 3.4 indicates that a total of 40 questions are contained in CPPT cutting across the six cognitive levels of Bloom (1975) which include knowledge (32.5%), comprehension (17.5%), application (20%), analysis (12.5%), Synthesis (7.5%) and Evaluation (10%). The Table also shows that 6 questions (15%) test students' achievement under the topic "Diffusion and its Applications in Living and Non-Living Systems"; 6 questions (15%) under "Osmosis and its Applications in Living and Non-Living Systems"; 7 questions (17.5%) under "Active Transport, Endocytosis and Exocytosis and their Applications"; 7 questions (17.5%) under "Cellular Respiration (Catabolism)"; 7 questions (17.5%) under "Photosynthesis (Anabolism)"; and 7 questions (17.5%) under "Mitosis and Meiosis and their Applications".

3. 5Es Instructional Package (5-EIP)

The 5-EIP consists of six (6) lessons designed by the researcher to present contents in Cell Physiology following the five phases of the 5Es Instructional Model as adopted from Bybee et al (2006). These phases include engage, explore, explain, elaborate and evaluate. The package is meant to guide the treatment of the experimental group by the researcher. Each lesson in the package is activity-based and was designed for 80 minutes (i.e. double period) to cover a topic in Cell Physiology. The entire package, comprising six topics, was covered in six weeks (i.e. one topic per week). Lessons in the package were guided by the content and objectives specified in the senior secondary Biology curriculum for the concept taught. The 5-EIP is presented in Appendix K.

3.5.1 Validation of the Instruments

The face and content validity of Science Process-Skill Acquisition Test (SPSAT) and Cell Physiology Performance Test (CPPT) were achieved by presenting the instruments to a panel of experts comprising:

i. Three Professors from Department of Science Education, Ahmadu Bello University, Zaria;
ii. An Associate Professor from the Department of Educational Psychology, Guidance and Counselling, Ahmadu Bello University, Zaria.
iii. Two experienced Biology teachers from Demonstration Secondary School, Ahmadu Bello University, Zaria, each with a minimum qualification of B.Sc (Ed) Biology and at least five (5) years teaching experience.

These experts were requested to critically assess CPPT and SPSAT with respect to:

i. the appropriateness of the test items for the level of students under study;
ii. whether or not the test items are clear to avoid ambiguity;
iii. whether or not the test items are related to the objectives of the study;
iv. checking for possible errors in the suggested answers; as well as
v. making suggestions that will be helpful in improving the quality of the instruments.

The 5Es Instructional Package (5-EIP) and lesson plans for the control group were also presented for validation to two Professors in the Department of Science Education, Ahmadu Bello University, Zaria. They were requested to check for the appropriateness of the treatment procedures and make suggestions for improvement where need be.

Some of the suggestions made for the improvement of SPSAT include the following:

i. Remove "Name of Student" for confidentiality;
ii. Replace "Examination Number" with ″Candidate's Number";
iii. Replace the blank space for "Gender" with "separate boxes for male and female";
iv. Indicate the process skill involved in each activity based on item specification;
v. Replace the word "Why?" with "Give reasons for your answer";
vi. Give title to each diagram as in "Figure 1, Figure 2, etc. and label appropriately;
vii. In item 3(i), reframe "In which of A and B…?" to "Which of the following - (A) or (B)…?" Same thing applies to item 7(i);
viii. In item 25, replace "What is observed...?" with "What do you observe…?"

Some of the suggestions made for the improvement of CPPT include the following:

i. Remove "Name of Student" for confidentiality;
ii. Replace "Examination Number" with ″Candidate's Number";

iii. State how candidates will respond to items e.g. by ticking or circling the options;

iv. Replace the blank space for “Gender” with “separate boxes for male and female”;

v. Indicate the Bloom’s cognitive taxonomy for each item in line with the CPPT Table of Specification;

vi. In item 3, reframe “Which of the following does NOT…?” to “…is NOT…?”

vii. In item 7, reframe “Which of the above-mentioned factors do affect…?” to “…does affect…?”

Some of the observations made on 5-EIP for improvement include the following:

i. The title “Lesson Plans for the Experimental Group” should be labelled as the package i.e. 5Es Instructional Package (5-EIP);

ii. In the “Explanation Phase”, teacher should ask students questions that will solicit for the explanations of concepts;

iii. In the “Elaboration Phase”, teacher should state exactly what will be done rather than leaving vague statements.

The suggestions so given and observations made were taken into consideration in the final formulation of the instruments. The letter to validators is presented in Appendix E.

3.5.2 ConceptSelected for the Study

The concept of 'Cell Physiology' was chosen for this study. The following topics were selected under this concept from the Senior Secondary Education Curriculum (Biology) developed by the NERDC (2012):

7. Diffusion and its Applications in Living and Non-Living Systems;
8. Osmosis and its Applications in Living and Non-Living Systems;
9. Active Transport, Endocytosis and Exocytosis and their Applications;
10. Cellular Respiration (Catabolism);
11. Photosynthesis (Anabolism);
12. Mitosis and Meiosis and their Applications.

The choice of these topics is informed by the researcher' s observations from a number of studies (Cimer, 2012; Agboghoroma&Oyovwi, 2015; Chatila& Al Husseiny, 2017) and WAEC Chief Examiner' s Reports (2009-2015) indicating their recurrent difficulty among students at the Senior Secondary School level. These topics were also chosen because of their abstractness and complexity (Etobro&Fabinu, 2017) as well as their requirement of multidisciplinary knowledge in science (Cimer, 2012). More so, WAEC (2013-2015) indicated that Senior Secondary School students are often not taught these topics or the teaching methods employed by the teachers in most cases are not appropriate.

3.6 Pilot Testing

Pilot testing was conducted using the Science Process Skill Acquisition Test (SPSAT) and Cell Physiology Performance Test (CPPT) on 50 SS II Biology students in GSS Tudun Saibu, which is not part of the study sample but part of the population for the study. The essence of pilot testing is to determine the characteristics of the test itemsin both instruments which include facility and discrimination indices. Pilot testing was also conducted to determine the reliability of instruments,a convenient time frame which the students would require to answer all the questionsas well as identify earlythe problems that may surface while administering the instruments during the actual study with a view to eliminating them. The school selected for this purpose is similar to those of the main study in terms of location, ownership and status.

SPSAT which consists of 30 alternative-to-practical test items and CPPT which initially consists of 50 multiple choice items were administered to the students by the researcher assisted by the SS II Biology teacher of the school. Instructions on how to answer the questions were read aloud and explained to the students by the researcher. Students were alsoallowed to ask questions for further clarification. A period of 1 hour 30 minutes (tentative) was allocated for the completion of each instrument to ensure that students answer the questions carefully and conveniently. The actual timing for each instrument wasdetermined by computing the average duration it took all the students to finish.

Problems and difficulties arising from the pilot testing were also carefully noted to improve upon the final instrument. At the completion of eachinstrumentthe question papers and answer sheetswere retrieved from students, marked and scored according to the marking schemeswhich were designed to ensure objectivity inscoring.

3.6.1 Reliability of the Instruments

The data obtained from pilot testing were analyzed to establish the reliability of the instruments as follows:

i. **SPSAT:**The test-retest and split-half (odd-even) method was used to estimate the reliability of SPSAT. The test and retest were conductedwithin an interval of two weeksas recommended by Tuckman (1975) and Sambo (2008). Pearson Product Moment Correlation (PPMC) statistic was used to determine the degree to which the two sets of scores correspond. The reliability coefficient (r) of SPSAT was found to be 0.84 which indicatesa high coefficient of stabilityof the instrument and therefore, its suitability foruse in the study. The test-retest reliability analysis of SPSATis presented in Appendix G. Split half (odd-even) method was also used to estimate the coefficient of internal consistency of SPSAT. Scores were obtained on the odd and even items of SPSAT on its first administration and the two sets of scores were correlated using the Spearman Rank Order Correlation statistic. The resulting split-half reliability coefficient ($r_{1/2}$) was 0.79. This describes the reliability of only half of the test. The Spearman-Brown formula was used to obtain the reliability of the full test which is 0.88. This indicates that SPSAThas a strong coefficient of internal consistency and is therefore reliable for use in this study.The split-half reliability analysis of SPSATis presented in Appendix H.

ii. **CPPT:**The test-retest method was used to determine the reliability of CPPT. The test and retest were conductedwithin an interval of two weeksas recommended by Tuckman (1975) and Sambo (2008). Pearson Product Moment Correlation (PPMC) statistic was used to estimate the degree to which the two sets of scores are associated. The reliability coefficient (r) of CPPTwas found to be 0.89 which indicatesa high coefficient of stabilityof the instrument and therefore, its suitability foruse in this study. The test-retest reliability analysis of CPPTis presented in Appendix I.

3.6.2 Item Analysis

The pilot study provided data for item analysis. The data collected were used to determine the facility index (F.I.) and Discrimination Index (D.I.) of each test item in the CPPT.

The facility index (F.I.) is a measure of the difficulty or ease of answering a test item. It indicates the percentage of candidates that got an item right (Wood, 1990). The facility index of each CPPT item was calculated using the formula proposed by Furst (1958) and Atadoga (2005), as follows:

$$F.I. = \frac{\text{RU} + \text{RL}}{\text{N}} \times 100$$

Where:

F.I. = Facility Index

RU = Number among upper 27% of the respondents who scored the item correctly.

RL = Number among lower 27% of the respondents who scored the item correctly.

N = Total number of respondents in each of the upper and lower groups.

The facility index (F.I) ranges from 0% to 100% (i.e. from 0 to 1) and the higher the value, the easier the item. Ranges above 0.70 are considered very easy items and might be a concept not worth testing. Ranges below 0.30 indicate difficult items and should be reviewed for possible ambiguity or thecontents need re-instruction. The recommended range of difficulty according to Miller, Linn and Gronlund(2009) is from 30-70% (i.e. from 0.3 to 0.7).In the present study, test items with facility indices from 30-70% or 0.3 - 0.7 were considered moderate and were therefore accepted for use as recommended by Usman (2008). Details of facility indices of CPPT items are presented in Appendix F.

The discrimination index (D.I.) of a test is a measure of its ability to distinguish between high and low achievers in the test as a whole (Abubakar, 2017). It is the capacity of a test item to separate the high and low ranking students or the good and not so good achievers in the entire test (Ibrahim, 2015). It is calculated using the formula proposed by Furst (1958) and Atadoga (2005), as follows:

$$D.I = \frac{\text{RU} - \text{RL}}{{}^{1}\!/_{2}\,\text{N}}$$

Where:

D.I. = Discrimination Index

RU = Number among upper 27% of the respondents who scored item correctly.

RL = Number among lower 27% of the respondents who scored the item correctly.

N = Total number of respondents in each of the upper and lower groups.

As a rule,a positive D.I (i.e. between 0 and +1) occurs when more students in the high group answered correctly than those in the low groupand a negative D.I (i.e. between -1 and 0) results when more students in the low group answered correctly than those in the high group. Zero D.I means equal numbers of high and low students answered correctly, so the item did not discriminate between the groups. The index of discrimination for CPPT itemsused for this study fell within 0.30-0.70 implying that the instrumentis suitable for the study (Usman, 2008). The discrimination indices of CPPT test items are presented in Appendix F.

3.7 Administration of the Treatment

The treatment administered to the subjects involved teaching the concept of Cell Physiology by the researcher to both the experimental and control groups for six weeks. The experimental group was exposed to the 5Es Instructional Package (5-EIP) while the control group was taught using Conventional Method.

3.7.1 Treatment of the Experimental Group

Based on the pretest scores of the subjects, the experimental group was divided into 9 sub-groups containing 6 students each. Each sub-group was made up of male and female students of different ability levels. The grouping was to allow for better interaction among students, neutralize any gender effect and permit easy management of such number of students. Regular classrooms and sometimes the Biology laboratory were used for the lessons. The detailed procedure for teaching the experimental group is contained in the 5Es Instructional Package (5-EIP) which is presented in Appendix I.

The treatment was based on the BSCS 5Es Instructional Model which is an inquiry-based teaching approach (Llewellyn, 2005). The 5Es Instructional Model sequences learning experiences so that students have the opportunity to construct their understanding of a concept during the teaching-learning process (Bybee, 2002). The model leads students through five phases of learning that are easily described using words that begin with the letter E, viz.: Engagement, Exploration, Explanation, Elaboration and Evaluation. These phases are as described by Bybee (2002) and Llewellyn (2005) as follows:

Phase 1 – Engagement Phase: The teacher captures students' interest and makes them curious about the topic and concepts to be learnt. This phase provides an opportunity for the teacher to find out what students already know or think they know about the topic and concepts to be developed.

Phase2 – Exploration Phase: Students interact with materials and ideas through classroom and small group discussions. This helps the students to acquire a common set of experiences so that they can compare results and ideas with their classmates.

Phase 3 – Explanation Phase: Students are provided an opportunity to connect their prior experiences with current learning and generate knowledge from main ideas. This phase also provides the opportunity for the introduction of formal language, scientific terms and content information that might make students' prior experiences easier to describe.

Phase 4 - Elaboration Phase: Students are provided with the opportunity to apply introduced concepts to new experiences. This phase helps students to make conceptual connections between new and prior experiences, connect ideas and deepen their understanding of concepts and processes.

Phase 5 - Evaluation Phase: This phase is centrally placed in the model and takes place in virtually every phase of the 5Es teaching (or learning) cycle. It provides a summative assessment of what students know.

The flowchart for the 5Es Instructional Model is presented in Figure 3.2.

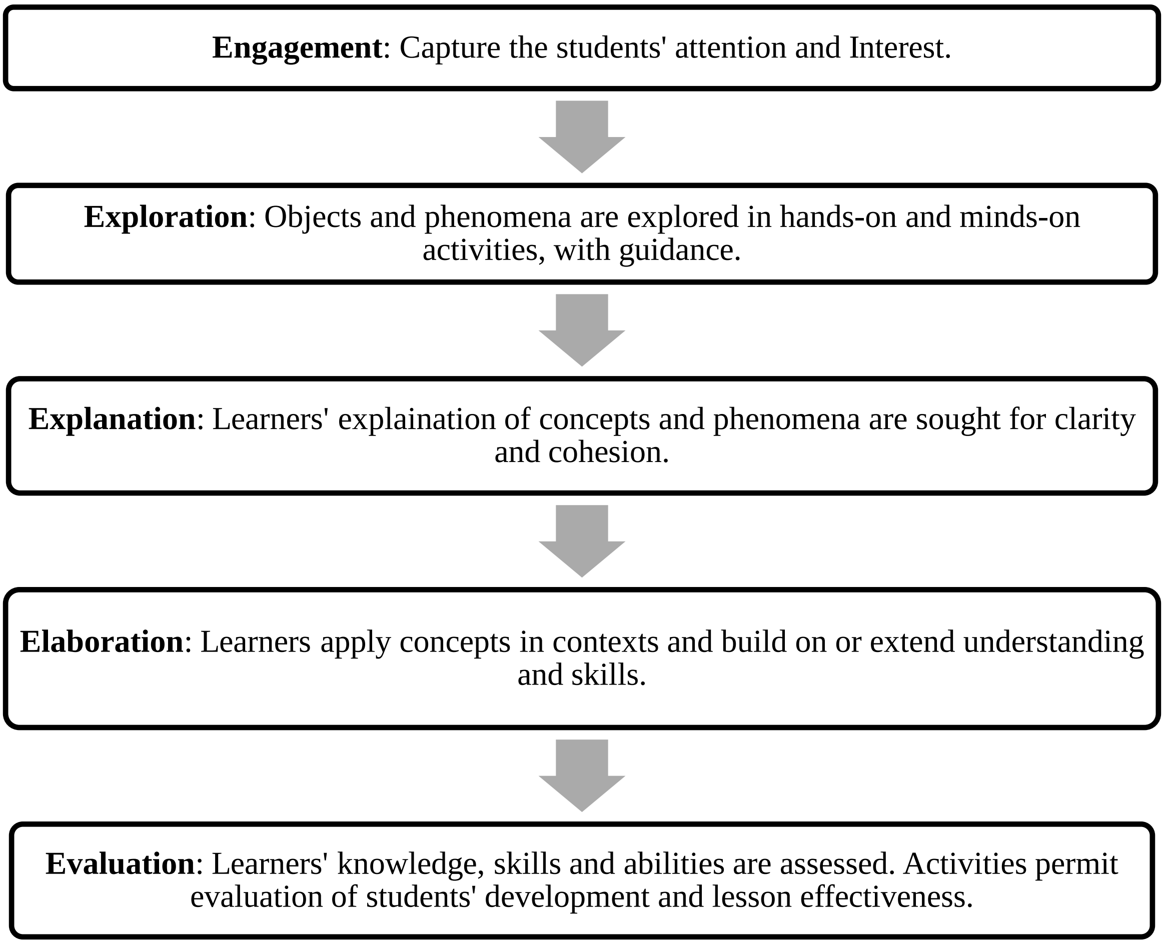

Fig 3.2: Flowchart Illustrating the 5Es Instructional Model.

Source: Bybee, et al. (2006)

During the treatment of the experimental group, subjects were taught the Cell Physiology concepts using the 5Es Model as illustrated and explained in Figure 3.2 to ensure that the teaching procedure is in conformity with the direction of the model. The subjects were allowed to explore the concepts through practical activities and problem solving as well as small-group discussions. The teaching lasted for six (6) weeks of 80 minutes (double period) per week. The 5-EIP was validated by two

Professors in the Department of Science Education, Ahmadu Bello University, Zaria. Details of the 5-EIP are presented in Appendix K.

3.7.2 Teaching the Control Group

The control group was taught all six topics under Cell Physiology by the researcher for six weeks. The lesson duration was same as that of the experimental group (i.e. 80 minutes per lesson) but instruction was done using the Conventional Method. The lessons were predominantly verbal presentations of the contents in each topic by the researcher using the chalkboard and charts displayed in cardboard papers as instructional aids. The students were expected to listen to the teacher and take down notes. Questions were entertained intermittently and assignments or notes were given at the end of each lesson. The lesson plans for the control group were validated by two Professors in the Department of Science Education, Ahmadu Bello University, Zaria. Details of the lesson plans for the control group are presented in Appendix L.

3.8 Data Collection Procedure

At the end of the six weeks treatment, the study subjects were tested to generate data in the following ways:

i. **Science Process-Skills Acquisition Test (SPSAT):** A post-test wasadministered and marked (over 70) using the marking scheme (Appendix B). The scores were collated into experimental and control groups as well as based on gender (i.e. male and female). After sorting, scores wereinput into the Statistical Package for Social Sciences (SPSS) version 20.0 and subject to analyses. This was to determine if there is any difference in the acquisition of science process-skills between the experimental and control groups as well as if any gender difference exists in the acquisition of science process-skillsamong the experimental group subjects.

ii. **Cell Physiology Performance Test (CPPT):**Posttest and post-posttest(after 2 weeks) were administered and marked (over 40) using the marking scheme (Appendix D). The scores were collated into experimental and control groups as well as based on gender (i.e. male and female). After sorting, the scores were input into SPSS version 20.0 and subject to analyses. This was to determine if there is any significant difference in the academic performance and retention in Cell Physiology between the experimental and control groups as well as if there is any gender difference in academic performance and retention among the experimental group subjects.

3.9 Procedure for Data Analysis

The data collected in this study wereanalyzed and used in answering the research questions as well as testing the null hypotheses as follows:

3.9.1 Answering the Research Questions

The data collected in this study were used in answering the research questions formulated to guide this study. Mean, Standard Deviationand Mean Differences of pretest and posttest scores of students were used. The research questions are outlined as follows:

Research Question 1: What is the difference between the mean science process-skills acquisition scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method?

Research Question 2: What is the difference between the mean science process-skills acquisition scores of male and female secondary school Biology students taught Cell Physiology using 5Es Instructional Model?

Research Question 3: What is the difference between the mean academic performance scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method?

Research Question 4: What is the difference between the mean academic performance scores of male and female secondaryschoolBiology students taught Cell Physiology using 5Es Instructional Model?

Research Question 5: What is the difference between the mean retention scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method?

Research Question 6: What is the difference between the mean retention scores of male and female secondaryschoolBiology students taught Cell Physiology using 5Es Instructional Model?

3.9.2 Testing the Null Hypotheses

The data collected in this study were also used to test the null hypotheses at $p \leq 0.05$ level of significance as follows:

HO_1: There is no significant difference between the mean science process-skills acquisition scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method.

This null hypothesis was tested using Independent Samples t-test.

HO_2: There is no significant difference between the mean science process-skills acquisition scores of male and female secondary school Biology students taught Cell Physiology using 5Es Instructional Model.

This null hypothesis was tested using Independent Samples t-test.

HO_3: There is no significant difference between the mean academic performance scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method.

This null hypothesis was tested using Independent Samples t-test.

HO_4: There is no significant difference between the mean academic performance scores of male and female secondaryschoolBiology students taught Cell Physiology using 5Es Instructional Model.

This null hypothesis was tested using Independent Samples t-test.

HO_5: There is no significant difference between the mean retention scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method.

This null hypothesis was tested using Independent Samples t-test.

HO_6: There is no significant difference between the mean retention scores of male and female secondaryschoolBiology students taught Cell Physiology using 5Es Instructional Model.

This null hypothesis was tested using Independent Samples t-test.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND DISCUSSION

4.1 Introduction

This study examines the impact of 5Es Problem-Solving Instructional Model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone, Kaduna State, Nigeria. This chapter gives the analysis and presentation of results as well as the discussion of findings. The Statistical Package for Social Sciences (SPSS) IBM Version 20 was used for the analysis. The chapter is presented under the following sub-headings:

4.2 Data Analysis and Result Presentation

4.2.1 Analysis of Research Questions

4.2.2 Test of Hypotheses

4.3 Summary of Major Findings

4.4 Discussion of Results

4.2 Data Analysis and Result Presentation

The data collected from the study using the Science Process-Skills Acquisition Test (SPSAT) and Cell Physiology Performance Test (CPPT) were analysed. Results obtained were used to answer the research questions and test the null hypotheses as follows:

4.2.1 Analysis of Research Questions

Research Question One: What is the difference between the mean science process-skills acquisition scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method?

To answer this research question, Means and Standard Deviations as well as mean differences of pretest and posttest SPSAT scores of students in the experimental and control groups were computed and used. The result is presented in Table 4.1:

Table 4.1: Mean and Standard Deviation Statistics of Pretest and Posttest SPSAT Scores for Students in Experimental and Control Groups.

Group	N	Pretest		Posttest		Mean Gain
		Mean	SD	Mean	SD	
Experimental	54	21.06	4.47	48.93	7.67	**27.87**
Control	56	20.61	4.76	38.21	9.62	**17.60**
Mean Difference		**0.45**		**10.72**		**10.27**

Table 4.1 shows that the pretest and posttest mean SPSAT scores of the experimental group are 21.06 and 48.93 with standard deviations of 4.47 and 7.67 respectively. The control group has pretest and posttest mean SPSAT scores of 20.61 and 38.21 with standard deviations of 4.76 and 9.62 respectively. The mean science process-skills acquisition gain for the experimental group is 27.87 while that of the control group is 17.60. The mean gain difference is 10.27. The higher mean gain of the experimental group over the control group as well as the large mean gain difference indicates the superiority of 5Es Instructional Model over Conventional Method in fostering the acquisition of science process-skills among secondary school Biology students in Cell Physiology.

Research Question Two: What is the difference between the mean science process-skills acquisition scores of male and female secondary school Biology students taught Cell Physiology using 5Es Instructional Model?

To answer this research question, Means and Standard Deviations as well as mean differences of pretest and posttest SPSAT scores of male and female students in the experimental group were computed and used. The result is presented in Table 4.2:

Table 4.2: Mean and Standard Deviation Statistics of Pretest and Posttest SPSAT Scores for Male and Female Students in Experimental Group.

Gender	N	Pretest		Posttest		Mean Gain
		Mean	SD	Mean	SD	
Male	34	21.24	4.82	50.12	7.63	**28.88**

Female	20	20.75	3.89	46.90	7.50	**26.15**
Mean Difference		**0.49**		**3.22**		**2.73**

Table 4.2 shows that the pretest and posttest mean SPSAT scores of the male students in the experimental group are 21.24 and 50.12 with standard deviations of 4.82 and 7.63 respectively. The female students have pretest and posttest mean SPSAT scores of 20.75 and 46.90 with standard deviations of 3.89 and 7.50 respectively. The mean science process-skills acquisition gain for the male students is 28.88 while that of the female students is 26.15. The mean gain difference is 2.73. The higher mean gain of the male students over their female counterparts as well as the small mean gain difference is indicative of the slight superiority of male students over female students in acquisition of science process-skills when taught Cell Physiology using 5Es Instructional Model.

Research Question Three: What is the difference between the mean academic performance scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method?

To answer this research question, Means and Standard Deviations as well as mean differences of pretest and posttest CPPT scores of students in the experimental and control groups were computed and used. The result is presented in Table 4.3:

Table 4.3: Mean and Standard Deviation Statistics of Pretest and Posttest CPPT Scores for Students in Experimental and Control Groups.

Group	N	Pretest		Posttest		Mean Gain
		Mean	SD	Mean	SD	
Experimental	54	13.13	3.60	26.80	5.76	**13.67**
Control	56	12.84	3.85	22.64	4.80	**9.80**
Mean Difference		**0.29**		**4.16**		**3.87**

Table 4.3 shows that the pretest and posttest mean CPPT scores of the experimental group are 13.13 and 26.80 with standard deviations of 3.60 and 5.76 respectively. The control group recorded pretest and posttest mean CPPT scores of 12.84 and 22.64 with standard deviations of 3.85 and 4.80 respectively. The mean academic performance gain for the experimental group is 13.67 while that of the control group is 9.80. The mean gain difference is 3.87. The higher mean gain of the experimental group over the control group as well as the considerable mean gain difference indicates the superiority of 5Es Instructional Model over Conventional Method in enhancing the academic performance of secondary school Biology students in Cell Physiology.

Research Question Four: What is the difference between the mean academic performance scores of male and female secondaryschoolBiology students taught Cell Physiology using 5Es Instructional Model?

To answer this research question, Means and Standard Deviations as well as mean differences of pretest and posttest CPPT scores of male and female students in the experimental group were computed and used. The result is presented in Table 4.4:

Table 4.4: Mean and Standard Deviation Statistics of Pretest and Posttest CPPT Scores for Male and Female Students in Experimental Group.

Gender	**N**	**Pretest**		**Posttest**		**Mean Gain**
		Mean	**SD**	**Mean**	**SD**	
Male	34	12.88	3.82	26.38	5.88	**13.50**
Female	20	13.55	3.25	27.50	5.62	**13.95**
Mean Difference		**0.67**		**1.12**		**0.45**

Table 4.4 shows that the pretest and posttest mean CPPT scores of the male students in the experimental group are 12.88 and 26.38 with standard deviations of 3.82 and 5.88 respectively. The female students have pretest and posttest mean CPPT scores of 13.55 and 27.50 with standard deviations of 3.25 and 5.62 respectively. The mean academic performance gain for the male students is 13.50 while that of the female students is 13.95. The mean gain difference is 0.45. The higher mean gain of the female students over their male counterparts as well as the small mean gain difference is indicative of the slight superiority of female students over male students in academic performance when taught Cell Physiology using 5Es Instructional Model.

Research Question Five: What is the difference between the mean retention scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method?

To answer this research question, Means and Standard Deviations as well as mean differences of posttest and post-posttest CPPT scores of students in the experimental and control groups were computed and used. The result is presented in Table 4.5:

Table 4.5: Mean and Standard Deviation Statistics of Posttest and Post-Posttest CPPT Scores for Students in Experimental and Control Groups.

Group	N	Posttest		Post-Posttest		Mean Gain
		Mean	SD	Mean	SD	
Experimental	54	26.80	5.76	29.94	5.49	**3.14**
Control	56	22.64	4.80	21.98	4.10	**-0.66**
Mean Difference		**4.16**		**7.96**		**3.80**

Table 4.5 shows that the posttest and post-posttest mean CPPT scores of the experimental group are 26.80 and 29.94 with standard deviations of 5.76 and 5.49 respectively. The control group recorded posttest and post-posttest mean CPPT scores of 22.64 and 21.98 with standard deviations of 4.80 and 4.10 respectively. The mean retentionabilityof the experimental group is 3.14 while that of the control group is -0.66. The mean retention difference is 3.80. The higher mean retention ability of the experimental group over the control group as well as the considerable mean retention difference indicates that 5Es Instructional Model is superior to Conventional Method in enhancing the retention ability of secondary school Biology students in Cell Physiology.

Research Question Six: What is the difference between the mean retention scores of male and female secondaryschoolBiology students taught Cell Physiology using 5Es Instructional Model?

To answer this research question, Means and Standard Deviations as well as mean differences of posttest and post-posttest CPPT scores of male and female students in the experimental group were computed and used. The result is presented in Table 4.6:

Table 4.6: Mean and Standard Deviation Statistics of Posttest and Post-Posttest CPPT Scores for Male and Female Students in Experimental Group.

Gender	N	Posttest		Post-Posttest		Mean Gain
		Mean	SD	Mean	SD	
Male	34	26.38	5.88	30.12	5.98	**3.74**
Female	20	27.50	5.62	29.65	4.66	**2.15**
Mean Difference		**1.12**		**0.47**		**1.59**

Table 4.6 shows that the posttest and post-posttest mean CPPT scores of the male students in the experimental group are 26.38and 30.12 with standard deviations of 5.88and 5.98 respectively. The female students have posttest and post-posttest mean CPPT scores of 27.50 and 29.65 with standard deviations of 5.62and 4.66 respectively. The mean retention ability of the male students is 3.74 while that of the female students is 2.15. The mean retention difference is 1.59. The higher retention ability of the male students over their female counterparts as well as the small mean retention difference indicatesthat male students are slightly superior over female students in their retention ability when taught Cell Physiology using 5Es Instructional Model.

4.2.2 Test of Hypotheses

For the purpose of this study, the stated null hypotheses were tested at P $\leq$ 0.05 level of significance as follows:

HO_1: There is no significant difference between the mean science process-skills acquisition scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method.

To test this null hypothesis, the posttest SPSAT scores of students in the experimental and control groups were subjected to Independent Samples t-test statistic and a summary of the analysis is presented in Table 4.7:

Table 4.7: Summary of Independent Samples t-test of Mean Posttest SPSAT Scores for Experimental and Control Groups

Group	N	Mean	SD	Mean Difference	Df	t-cal	P	Remark
Experimental	54	48.93	7.67	10.72	108	6.44	0.001	Significant
Control	56	38.21	9.62					

Significant at P$\leq$ 0.05

Table 4.7 shows a p-value of 0.001 observed at degree of freedom of 108. This p-value is less than the 0.05 level of significance, indicating that there is a significant difference between the mean science process-skills acquisition scores of students taught Cell Physiology using 5Es Instructional Model and those taught using Conventional Method. The observed difference is in favour of the experimental group which was exposed to the 5Es Instructional Model. Hence, the null hypothesis is rejected, implying that 5Es Instructional Model significantly fosters the acquisition of science process-skills among secondary school Biology students than Conventional Method.

HO_2: There is no significant difference between the mean science process-skills acquisition scores of male and female secondary school Biology students taught Cell Physiology using 5Es Instructional Model.

To test this null hypothesis, the posttest SPSAT scores of male and female students in the experimental group were subjected to Independent Samples t-test statistic and a summary of the analysis is presented in Table 4.8:

Table 4.8: Summary of Independent Samples t-test of Mean Posttest SPSAT Scores for Male and Female Students in Experimental Group

Group	N	Mean	SD	Mean Difference	Df	t-cal	P	Remark
Male	34	50.12	7.63	3.22	52	1.51	0.138	Not Significant
Female	20	46.90	7.50					

Significant at P≤ 0.05

Table 4.8 reveals a p-value of 0.138 observed at degree of freedom of 52. This p-value is greater than the 0.05 level of significance indicating that there is no significant difference between the mean science process-skills acquisition scores of male and female students taught using 5Es Instructional Model. Hence, the null hypothesis is retained implying that gender has no significant influence on secondary school Biology students' acquisition of science process-skills when taught Cell Physiology using 5Es Instructional Model.

HO_3: There is no significant difference between the mean academic performance scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method.

To test this null hypothesis, the posttest CPPT scores of students in the experimental and control groups were subjected to Independent Samples t-test statistic and a summary of the analysis is presented in Table 4.9:

Table 4.9: Summary of Independent Samples t-test of Mean Posttest CPPT Scores for Experimental and Control Groups

Group	N	Mean	SD	Mean Difference	Df	t-cal	P	Remark
Experimental	54	26.80	5.76	4.16	108	4.11	0.001	Significant
Control	56	22.64	4.80					

Significant at $P \leq 0.05$

Table 4.9 shows a p-value of 0.001 observed at degree of freedom of 108. This p-value is less than the 0.05 level of significance, indicating that there is a significant difference between the mean academic performance scores of students taught Cell Physiology using 5Es Instructional Model and those taught using Conventional Method. The difference so observed is in favour of the experimental group which was exposed to the 5Es Instructional Model. Hence, the null hypothesis is rejected, implying that 5Es Instructional Model significantly enhances secondary school Biology students' academic performance in Cell Physiology than Conventional Method.

HO_4: There is no significant difference between the mean academic performance scores of male and female secondaryschoolBiology students taught Cell Physiology using 5Es Instructional Model.

To test this null hypothesis, the posttest CPPT scores of male and female students in the experimental group were subjected to Independent Samples t-test statistic and a summary of the analysis is presented in Table 4.10:

Table 4.10: Summary of Independent Samples t-test of Mean Posttest CPPT Scores for Male and Female Students in Experimental Group

Group	N	Mean	SD	Mean Difference	Df	t-cal	P	Remark
Male	34	26.38	5.88	1.12	52	-0.69	0.496	Significant
Female	20	27.50	5.62					

Significant at $P \leq 0.05$

Table 4.10 reveals a p-value of 0.496 observed at degree of freedom of 52. This p-value is greater than the 0.05 level of significance indicating that there is no significant difference between the mean academic performance scores of male and female students taught using 5Es Instructional Model. Hence, the null hypothesis is retained, implying that gender does not significantly influence secondary school Biology students' academic performanceinCell Physiology when taught using 5Es Instructional Model.

HO_5: There is no significant difference between the mean retention scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method.

To test this null hypothesis, the post-posttest CPPT scores of students in the experimental and control groups were subjected to Independent Samples t-test statistic and a summary of the analysis is presented in Table 4.11:

Table 4.11: Summary of Independent Samples t-test of Mean Post-Posttest CPPT Scores for Experimental and Control Groups

Group	N	Mean	SD	Mean Difference	Df	t-cal	P	Remark
Experimental	54	29.94	5.49	7.96	108	8.64	0.001	Significant
Control	56	21.98	4.10					

Significant at $P \leq 0.05$

Table 4.11 shows a p-value of 0.001 observed at degree of freedom of 108.This p-value is less than the 0.05 level of significance, indicatingthat there is a significant difference between the mean retention scores of students taught Cell Physiology using 5Es Instructional Model and those taught using Conventional Method. The observed difference is in favour of the experimental group which was exposed to the 5Es Instructional

Model. Hence, the null hypothesis is rejected implying that 5Es Instructional Model significantly improves secondary school Biology students' retention ability in Cell Physiology than Conventional Method.

HO_6: There is no significant difference between the mean retention scores of male and female secondaryschoolBiology students taught Cell Physiology using 5Es Instructional Model.

To test this null hypothesis, the post-posttest CPPT scores of male and female students in the experimental group were subjected to Independent Samples t-test statistic and a summary of the analysis is presented in Table 4.12:

Table 4.12: Summary of Independent Samples t-test of Mean Post-Posttest CPPT Scores for Male and Female Students in Experimental Group

Group	N	Mean	SD	Mean Difference	Df	t-cal	p	Remark
Male	34	30.12	5.98	0.47	52	0.30	0.766	Not Significant
Female	20	29.65	4.66					

Significant at $P \leq 0.05$

Table 4.12 reveals a p-value of 0.766 observed at degree of freedom of 52. This p-value is greater than the 0.05 level of significance indicating thatthere is no significant difference between the mean retention scores of male and female students taught using 5Es Instructional Model. Hence, the null hypothesis is retained, implying that gender has no significant influence on secondary school Biology students' retention abilitywhen taught Cell Physiology using 5Es Instructional Model.

4.3 Summary of Major Findings

Based on the results of this study, the following findings were made:

1. There is a statistically significant difference between the mean science process-skills acquisition scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method.
2. There is no statistically significant difference between the mean science process-skills acquisition scores of male and female secondary school Biology students taught Cell Physiology using 5Es Instructional Model.
3. There is a statistically significant difference between the mean academic performance scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method.
4. There is no statistically significant difference between the mean academic performance scores of male and female secondaryschoolBiology students taught Cell Physiology using 5Es Instructional Model.

5. There is a statistically significant difference between the mean retention scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model and those taught the same concept using Conventional Method.
6. There is no statistically significant difference between the mean retention scores of male and female secondaryschoolBiology students taught Cell Physiology using 5Es Instructional Model.

4.4 Discussion of Results

The results in Table 4.1 show that students in the experimental group had a higher mean science process-skills acquisition score than those in the control group. The difference was significant as indicated by the t-test analysis in Table 4.7. This signifies that students taught Cell Physiology concepts using 5Es Instructional Model had a significantly higher mean science process-skills acquisition score than those taught using Conventional Method. By implication, the 5Es Instructional Model was able to foster a significantly higher acquisition of science process-skills than the Lecture Method. It may be argued that students exposed to the 5Es Instructional Model had the opportunity to observe, measure, record and interpret data while they were involved in the investigative activities as against those exposed to Conventional Method. The significant difference can further be attributed to the fact that the 5Es Instructional Model provides the opportunity for students in the experimental group to experience interactive learning wherein they communicate, infer and predict future occurrences from data collected while they explore materials. This finding agrees with the earlier findings of Boddy, Watson and Abusson (2003), Hirca (2015) and Cakir (2017). These researchers revealed that students exhibited significant improvements in science process-skills acquisition as a result of treatment with the 5Es Model as compared to the Traditional Lecture Method. From the meta-analysis undertaken by Cakir (2017), this finding corroborates those of Biyikli (2013), Acisli (2014) and Ozturk, Geren and Dokme (2015). The finding of this study also concurs with the assertion of CPB (2002) that through constructivist teaching particularly with the 5Es Model, better learning experiences and new patterns of thinking are fostered among students.The finding also establishes empirical evidence for the statement of Senan (2013) that the 5Es Instructional Model promotes strategies for inquiry as well as acquisition of skills such as the science process-skills, creative thinking and problem-solving skills that are essential to an inquiring mind.The finding also provides support to the research findings of Chebii, Wachanga and Kiboss (2012), Yadav and Mishra (2013), Abungu, Okere and Wachanga (2014) and Ghumdia (2016) on the efficacy of inquiry-based teaching approaches in fostering science process-skills acquisition among students better than the traditional teaching approach.

The findings in Table 4.2 reveal that male students in the experimental group had a higher mean science process-skills acquisition score than their female counterparts. The difference was however not significant as shown by the t-test analysis in Table 4.8. This indicates that male and female students taught Cell Physiology concepts using 5Es Instructional Model do not significantly differ in their mean science process-skills acquisition score. By implication, the 5Es Instructional model is gender-friendly as it was able to foster (almost equally) the acquisition of science process-skills among male and female students. This may be due to the fact that activities based on the 5Es Instructional Model to which the experimental group was exposed enabled both male and female students in their heterogeneous groups to practice the art of scientific inquiry, thereby promoting their science process-skills abilities. This finding is in line with the research findings of Njoku (2002), Ibe (2006), Nwagbo and Chukelu (2011), Usman, Ahmed and Tijjani (2014), Ugwanyi (2015) and Rabacal (2016). Njoku (2002) found that boys in heterogeneous practical groups do not dominate their female counterparts in basic process-skills like measurement, observation, communication and inference. Ibe (2006), Nwagbo and Chukelu (2011) and Usman, Ahmed and Tijjani (2014) in their independent studies revealed that gender has no significant effect on levels of acquisition of science process-skills among secondary school students when exposed to inquiry-based approaches.Ugwanyi (2015) and Rabacal (2016) found no significant gender differences in the acquisition and mastery of science process skills. This finding however, contradicts the research outcomes of Abungu, Okere and Wachanga (2014), Omiko (2015), Guevara (2015), Ghumdia (2016), Ongowo (2017) and Widdina, Rochintaniwati and Rusyati (2018) who in their independent studies indicated the existence of gender differences in the mastery of science process skills in favour of boys. On the other hand, Ong et al. (2012) and Zeidan and Jayosi (2015) in their separate studies, found gender differences in favour of girls with regard to knowledge of both basic and integrated science process skills.

The results in Table 4.3 show that students in the experimental group had a higher mean academic performance score than those in the control group. The difference was significant as indicated by the t-test analysis in Table 4.9. This signifies that students taught Cell Physiology concepts using 5Es Instructional Model had a significantly higher mean academic performance score than those taught using Conventional Method. By implication, the 5Es Instructional Model had significantly enhanced the academic achievement of students than the Lecture Method. This may be accounted for by the 5Es Instructional Model’s capacity to engage students in knowledge construction, drawing from their previous experiences and creating new, more concrete experiences as well as providing opportunities for collaborative learning and discussions which lead to better understanding of concepts and thus, improved academic performance. This finding is in support of the research findings of BSCS (2006), Balci (2006), Kaynar (2007), Ndioho (2007), Ozlem and Jale (2010) and Ibrahim (2015)which indicated that 5Es Learning Modelis significantly more effective in enhancing students’ academic performance in a number of Biology concepts than Traditional Lecture Method. Similar findings were indicated by Pulat (2009) in Mathematics, Bunkure (2012) in Physics as well as Umahaba (2016) and Jack (2017) in Chemistry. Meta-analytic studies of Anil and Batdi (2015), Ayaz and Sekerci (2015), Ural and Bumen (2016), Sarac (2017) and Cakir (2017) also confirmed the results of this study with a broad, positive and significant effect of the 5Es Instructional Model on academic achievement of students. On the contrary, Keskin (2008) and Yildiz, Ergin and Kocakuluh (2012) have reported negative impacts of the 5Es Instructional Model on the academic achievement of students in Turkey.

The findings in Table 4.4 reveal that female students in the experimental group had a higher mean academic performance score than their male counterparts. The difference was however not significant as shown by the t-test analysis in Table 4.10. This indicates that male and female students taught Cell Physiology concepts using 5Es Instructional Model do not significantly differ in their mean academic performance scores. This implies that 5Es Instructional Model is gender-friendly as it equally improves (without causing any significant variance in) the academic performance of male and female students exposed to it. This observation could be attributed to the fact that the 5Es Instructional Model, in its exploration phase, allows for the active participation of students irrespective of gender. Its explanation and elaboration phases also give room for intellectual discuss where both male and female students are opportune to contribute meaningfully to the lessons as well as complement one another's knowledge based on their observations in the exploration phase. The finding agrees with earlier research findings of Hiccan (2008), Ibrahim (2015) and Umahaba (2016). These independent studies revealed no significant difference between male and female students in their academic performance in Mathematics, Biology and Chemistry respectively, when exposed to 5Es Learning Cycle Model. Studies carried out by Wachanga (2002), Wabungu and Changeiywo (2008) and Olatoye, Aderogba and Aanu (2011) also showed no significant differences in the academic achievement of boys and girls when taught using collaborative and activity-based strategies. However, this finding contradicts those of Bunkure (2012) and Dahiru (2013) which indicated significant gender differences in favour of female students. Ibrahim (2012), Olorukooba, Lawal and Jiya (2012) and Umar (2013) on the other hand, reported significant gender differences in academic performance favouring males.

The results in Table 4.5 show that the experimental group subjects had a higher mean retention score than the control group subjects. The difference was significant as indicated by the t-test analysis in Table 4.11. This signifies that students taught Cell Physiology concepts using 5Es Instructional Model significantly retains better than those taught using Conventional Method. By implication, the 5Es Instructional model was able to promote better retention ability than the Conventional Method. This may be attributed to the high level of interaction among learners, teachersand resources in the learning environment which is inherent in the 5Es Instructional Model. During instruction based on the 5Es Model, students are allowed to describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge and communicate their ideas to other students. These result in students being able to generate, acquire, process and store facts about the concept from a variety of stimuli as well as recall them with ease weeks after exposure to treatment. This finding affirms the assertion of Boddy, Watson and Aubusson (2003) that using the 5Es Instructional Model in science teaching helps students to better retain concepts in their minds. The finding is also in accord with the research outcomes of Udogu and Njelita (2010), Sakalli (2011), Bunkure (2012) and Ibrahim (2015). These independent studies agree on the efficacy of 5Es Instructional Model in significantly improving the retention scores when compared to those exposed to the Traditional Lecture Method. Similarly, Anil andBatdi (2015) in a meta-analytic study, revealed that students' retention scores when taught using 5Es Model were significantly better than when Traditional Teaching Methods were used.

The findings in Table 4.6 reveal that male students in the experimental group had a higher mean retention score than their female counterparts. The difference was however not significant as shown by the t-test analysis in Table 4.12. This indicates that male and female students taught Cell Physiology concepts using 5Es Instructional Model do not significantly differ in their mean retention scores. By implication, the 5Es Instructional model is gender-friendly in regards to secondary school students' retention ability as it engenders no significant difference between the groups. This is attributable to the fact that during instruction using the 5Es Model, both male and female students in the experimental group were very active in discovering concepts of science and associating these concepts with situations in real life as they implemented them. In this process, students in their heterogeneous groups are able to utilize their critical thinking, problem-solving andcommunication skills which create avenues for deeper processing of information and hence, better retention of learnt concepts. This finding is in accord with the earlier findings of Bunkure (2012) and Ibrahim (2015). In the findings of Bunkure (2012), there is no significant difference in students’ retention scores with reference to gender when exposed to the 5Es instructional model. Ibrahim (2015) also found that male and female Pre-NCE Biology students exposed to 5Es Teaching Cycle recorded no significant difference in their retention abilities. This finding also substantiates the finding of Lakpini (2006) that gender has no significant effect on secondary school students’ retention ability in Biology.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This study aims at the investigation of the impact of 5Es Problem-Solving Instructional Model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone, Kaduna State, Nigeria. In this chapter, the summary of the procedures for data collection, analysis and findings of the study are presented. The conclusion and recommendations arising from the study as well as suggestions for further studies are also outlined under the following sub-headings:

5.2 Summary

5.3 Summary of Major Findings

5.4 Conclusion

5.5 Contributions to Knowledge

5.6 Recommendations

5.7 Limitations of the Study

5.8 Suggestions for Further Studies

5.2 Summary

This study investigates the impact of 5Es Problem-Solving Instructional Model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria

Education Zone, Kaduna State, Nigeria. Six research questions and six null hypotheses were formulated to guide the study.

In this study, the reviewed literature are related to the research topic and based on the following sub-headings: Historical Perspective of Science Education in Nigeria;Philosophy and Objectives of Science Education;Philosophy and Objectives of Biology Education;Problems of Teaching and Learning Biology in Nigerian Senior Secondary Schools;Science Process-Skills Acquisition among Senior Secondary School Students;Relevance of Science Process-Skills to Science Education;Students' Academic Performance in Biology at Senior Secondary Schools;Trends of Senior Secondary School Students' Performance in Cell Physiology Concepts;Instructional Strategies in the Teaching and Learning of Biology;The Concept of 5Es Instructional Model;5Es Instructional Model and Process-Skills Acquisition;5Es Instructional Model and Academic Performance in Biology;5Es Instructional Model and Retention Ability of Senior Secondary School Students; Gender and Science Process-Skills Acquisition; Gender and Academic Performance in Biology; Gender and Retention Ability of Students in Biology. Overview of Similar Studies; as well as Implications of the Literature Reviewed for the Present Study.

The study adopts the quasi-experimental design, specifically the pretest-posttest,non-equivalent groups design. Pre-test was administered before treatment to ensure homogeneity of the groups as well as measure the students' initial level of science process-skills acquisition and academic performance in Cell Physiology. The students in the experimental group were taught using 5Es Instructional Package (5-EIP) following the model adapted from Bybee, et al (2006) while those in the control group were taught using Conventional Method. Treatment lasted for six weeks each.The concept of Cell Physiology as derived from the Senior Secondary Biology Curriculum by NERDC (2012) was taught in six lessons (one topic per week for each group). The concept taught covered: Diffusion and its Applications in Living and Non-Living Systems; Osmosis and its Applications in Living and Non-Living Systems; Active Transport, Endocytosis and Exocytosis and their Applications; Cellular Respiration (Catabolism); Photosynthesis (Anabolism); as well as Mitosis and Meiosis and their Applications. Posttest was administered immediately after treatment to measure students' process-skills acquisition and academic performance in the concept taught. Two weeks after posttest, post-posttest was administered to both groups to measure their retention ability of learnt concepts. Two (2) instruments were used for data collection, namely, Science Process Skills Acquisition Test (SPSAT) and Cell Physiology Performance Test (CPPT). SPSAT is a 30-item alternative-to-practical test with a reliability coefficient of 0.84 and internal consistency of 0.79 while CPPT is a 40-item multiple-choice test with a reliability coefficient of 0.89. One hundred and ten (110) SS2 Biology students constituted the sample for this study and were derived from two (2) co-educational schools randomly sampled from the thirty (30) public senior secondary schools in Zaria Education Zone. The population of this study is made up of seven thousand, eight hundred and seven (7,807) SS2 Biology students in the study area.

The data collected were analyzed using descriptive statistics of Means and Standard Deviations to answer the research questions as well as inferential statistics of Independent Samples t-test to test the null hypotheses at $p \leq 0.05$ levels of significance. All analyses were done using the Statistical Package for Social Sciences (SPSS) IBM Version 20.

5.3 Summary of Major Findings

The following are the major findings of this study:

7. There is a statistically significant difference between the mean science process-skills acquisition scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model

(i.e. the experimental group) and those taught the same concept using Conventional Method (i.e. the control group) in favour of the experimental group.

8. There is no statistically significant difference between the mean science process-skills acquisition scores of male and female secondary school Biology students taught Cell Physiology using 5Es Instructional Model (experimental group).
9. There is a statistically significant difference between the mean academic performance scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model (i.e. the experimental group) and those taught the same concept using Conventional Method (i.e. the control group) in favour of the experimental group.
10. There is no statistically significant difference between the mean academic performance scores of male and female secondaryschoolBiology students taught Cell Physiology using 5Es Instructional Model (experimental group).
11. There is a statistically significant difference between the mean retention scores of secondary school Biology students taught Cell Physiology using 5Es Instructional Model (i.e. the experimental group) and those taught the same concept using Conventional Method (i.e. the control group) in favour of the experimental group.

12. There is no statistically significant difference between the mean retention scores of male and female secondaryschoolBiology students taught Cell Physiology using 5Es Instructional Model (experimental group).

5.4 Conclusion

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

1. The acquisition of science process-skills can be fostered significantly by the use of 5Es Instructional Model.
2. Academic performance in Cell Physiology concepts can be enhanced significantly by employing the 5Es Instructional Model.
3. 5Es Instructional Model promotes meaningful and concrete learning which strengthens the retention of learnt concepts in Cell Physiology among students.
4. The use of 5Es Instructional Model is gender-friendly as it engenders better acquisition of science process-skills and boosts academic performance as well as knowledge retention among both male and female students.

5.5 Contributions to Knowledge

The concern of this study was to explore the impact of 5Es Problem-Solving Instructional Model on science process-skills acquisition, performance and retention in Cell Physiology among secondary school Biology students in Zaria Education Zone, Kaduna State, Nigeria. The findings of this study have significant contributions and great implications for educational practices in Nigeria in the following ways:

1. The researcher was able to establish that using the 5Es Problem-Solving Instructional Model adapted from Bybee, et al (2006) to teach Cell Physiology concepts is highly effective in fostering the acquisition of science process-skills which include the ability to observe, measure, classify, communicate, infer and predict among secondary school Biology students. This is particularly important for classroom practice as teaching for the acquisition of science process skills is now becoming a rare and declining phenomenon.
2. The findings of this study have added to the pool of existing knowledge in empirical literatures especially on the efficacy of the 5Es Instructional Model in fostering the acquisition of science process-skills among secondary school students in Nigeria. Previous researches on this subject have mostly been from countries like Turkey.
3. The study also establishes that using the 5Es Problem-Solving Instructional Model to teach Cell Physiology concepts is highly effective in enhancing secondary school Biology students' academic performance and knowledge retention. This is of paramount importance since Biology teachers especially in public schools do

not normally use this method to teach difficult and abstract Biology concepts like Cell Physiology.

4. The ability of 5Es Instructional Model to significantly foster science process-skills acquisition, academic performance and knowledge retention among secondary school Biology students in comparison to the Conventional Method has addressed the need for a single strategy that could develop students cognitively, affectively and psychomotively especially in secondary schools.
5. The Science Process-Skills Acquisition Test (SPSAT) was adapted from Ajagun (1998) and tailored to measure SS2 Biology students' acquisition of the six basic science process skills. This instrument, being highly stable both over time and within its items, can be employed as a reliable instrument for assessing the acquisition of basic science process-skills among senior secondary school students. Thus, it can be adopted or adapted by researchers for similar or related studies.
6. The Cell Physiology Performance Test (CPPT) was adapted from past standardized test items of WASSCE (1998-2018) taking cognisance of the six levels of the cognitive domain spelt out by Bloom (1975) to test SS2 Biology students' academic performance and retention in Cell Physiology concepts. The instrument is valid and has a high stability over time. It can therefore be adopted or adapted

for use in similar or related studies to measure senior secondary school students' performance and retention Cell Physiology.

7. The researcher also developed the 5Es Instructional Package (5-EIP) to teach SS2 Biology students six topics under the concept of Cell Physiology. The package was found to be effective in promoting students' science process-skills acquisition, academic performance and knowledge retention. So, it can be adopted to teach the same concepts in Senior Secondary Schools or adapted to teach other difficult and abstract concepts in Biology or other science subjects like Chemistry, Physics and Mathematics.
8. This research work also examined the effect of gender on students' science process-skills acquisition, retention and academic performance in Cell Physiology when taught using 5Es Instructional Model. The strategy was found to be gender-friendly across the dependent variables and is therefore highly recommended for classroom instruction in co-educational and single-sex schools alike.
9. From the knowledge of the researcher, this work is the first of its kind in Zaria Education Zone, Kaduna State, Nigeria. It could be replicated by other researchers in other education zones within and outside the state.

5.6 Recommendations

Based on the findings of this study, the following recommendations are made, bearing in mind the stated objectives and hypotheses:

1. Biology teachers should consistently encourage students to actively participate in classroom explorations, discussions and elaboration of learnt concepts for better acquisition of process-skills, enhanced performance and longer retention.
2. 5Es Model of instruction requires the use of materials as it is activity based. Therefore, principals and senior masters should encourage and support Biology teachers in providing instructional materials to facilitate classroom explorations and hands-on learning for better acquisition of process skills, performance and retention.
3. Biology teachers should improvise where materials are not available or inadequate.
4. Biology teachers should frequently employ the 5Es Model in teaching challenging concepts like Cell Physiology for enhanced academic performance of students.

5. The Federal and State Governments through the Ministries of Education should provide standard Biology laboratories in secondary schools to enable Biology teachers use the 5Es Model to teach for the acquisition of science process-skills.
6. Curriculum planners and developers like the NERDC should integrate aspects of the 5Es Instructional Model such as engaging students, exploring materials, explaining concepts, elaborating contexts and evaluating instruction in subsequent Biology curricula for better implementation of the model in classroom instruction.
7. Professional bodies like STAN in collaboration with the Federal and State Ministries of Education should embark on nationwide re-training of Biology teachers to design and implement classroom instructions based on the 5Es Model through regular national, state and local seminars, workshops and conferences.
8. Teacher Educators in Nigerian Universities and Colleges of Education should integrate the 5Es Instructional Model in their teacher-training sessions as this will expose theprospective Biology teachers to its potentials, equip them with the requisite skills as well as inculcate in them the desire to implement this strategy in teaching Biology while in service.

5.7 Limitations of the Study

The following limitations were noticed in the course of this study:

1. The study was restricted to only two public schools and to only SS2 Biology students in Zaria Education Zone of Kaduna State, Nigeria. This makes the generalization of the results fairly narrow and perhaps not applicable nationwide.
2. Tardiness or lack of punctuality was a serious challenge to the researcher during treatment as some students (especially the male students) usually absconded from school while some were absent without any obvious reason.
3. Poor communication skills in English Language on the part of some students was a problem as the researcher often had to resort to the native dialect (i.e. Hausa Language) in explaining some concepts to the students during treatment.
4. Inadequate classroom furniture as well as lack of certain laboratory apparatus needed for the study was also a challenge during treatment.

5.8 Suggestions for Further Studies

The following suggestions are put forward for further studies:

1. Similar studies could be conducted in other science subjects undertaken in Senior Secondary Schools such as Physics, Chemistry, Agricultural Science and Mathematics among others.
2. Studies of this kind could be extended to other educational levels such as primary schools, junior secondary schools and higher institutions of learning like colleges of education, polytechnics, monotechnics and universities.
3. Similar studies could also be carried out on other education zones in Kaduna State as well as other states in the federation for a wider and more generalized result.
4. The study could be extended to accommodate other dependent variables where empirical literature are lacking (or limited) such as students' perception, anxiety, self-efficacy, acquisition of integrated science process-skills, scientific creativity and scientific attitudes among others.
5. A survey of in-service science teachers' awareness, mastery and implementation of the 5Es Instructional Model in senior secondary schools could be undertaken to keep abreast of the status-quo in the utilization of innovative teaching strategies in Nigerian schools.
6. The 5Es Problem-Solving Instructional Model could be compared against other innovative teaching strategies such as Guided-

Inquiry, Process Approach, Laboratory-Based Approach and Project Method among others, to determine its relative efficacy.

7. There is also need to determine the effects of variables like gender, grade level and school location on the acquisition and mastery of basic and/or integrated science process-skills among students in primary, secondary and tertiary institutions in Nigeria.
8. Studies can also be carried out on the relationship between students' process-skills acquisition and their academic performance in Biology as well as to determine whether students' acquisition of science process skills can significantly predict their achievement in the subject.
9. Further studies should also be carried out on the reasons behind the limitations encountered in this study as well as their possible remedies with a view to alleviating them in future researches conducted in Zaria Education Zone.

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APPENDIX A

SCIENCE PROCESS-SKILLS ACQUISITION TEST (SPSAT)

Time allowed: 1 hour.

Instruction: Attempt all questions. Fill in the blank spaces provided in this booklet and in the case of multiple questions, circle the letter(s) that corresponds to your chosen option(s). **DO NOT START UNTIL YOU ARE TOLD TO DO SO.**

School Name: ____

Candidate's Number: ______________________ Gender ☐ Male ☐ Female

SECTION I

Figure 1 shows three charts (A, B & C). Study them carefully and use them to answer questions 1-7.

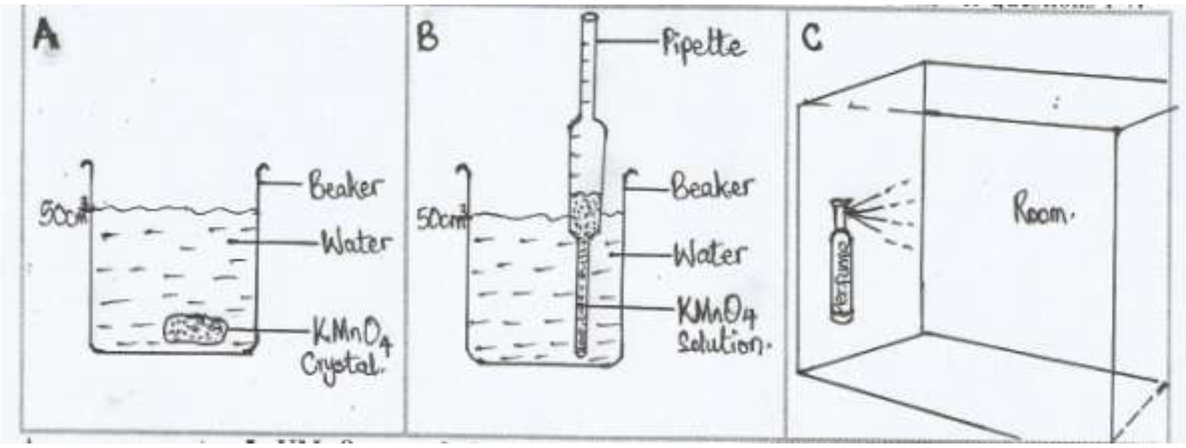


Figure 1: A represents a 5g $KMnO_4$ crystal placed at the bottom of a beaker containing $50cm^3$ of distilled water.
B represents $5cm^3$ $KMnO_4$ solution delivered at the bottom of a beaker containing $50cm^3$ of distilled water.
C represents a $5cm^3$ container of perfume sprayed at one corner of a small room.

1. **OBS:** In which state of matter is the:
   i. $KMnO_4$ crystals in A? ______________________________
   ii. $KMnO_4$ solution in B? ______________________________
   iii. Perfume in C? ______________________________

2. **OBS:** When left for 5 minutes, what happens to the distilled water in A and B?

   ____

   ____

3. **CLS:** i. Which of the following - (A) or (B) - will diffusion take place faster? _____
   ii. Give reasons for your answer: ____

   ____

4. **PRD:** What do you think will happen to the rate of diffusion if warm distilled water was used?____

   ____

5. **MEA:** If diffusion were to be complete in 5 minutes when cold water is used, how much time would be required to complete diffusion if warm water is used instead? ***(Tick the right option)***
   a. More than 5 minutes.
   b. Exactly 5 minutes.
   c. Less than 5 minutes.

6. **OBS:** When left for 5 minutes, what happens to the sprayed perfume in C? ________

   ____

   ____

7. **CLS:** i. Which of the following - (B) or (C) - do you think diffusion will take place faster? ______________
   ii. Give reasons for your answer: ____

   ____

   ____

Figure 2 shows a graph which represents the number of molecules of three substances (P, Q and R) that diffuse per unit time. Study the graph carefully and use it to answer question 8.

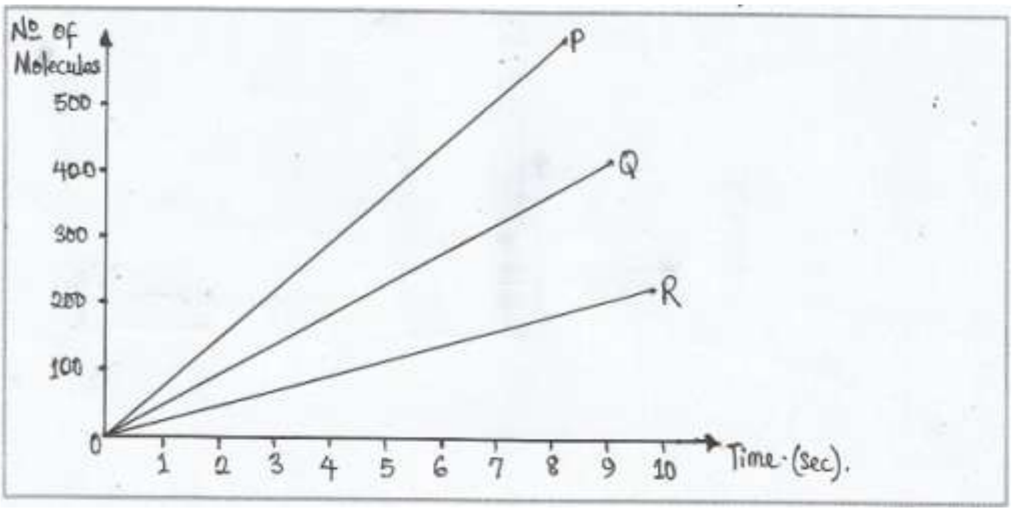


Figure 2:Graph of rate of diffusion of three substances (P, Q and R).

8. **COM:** Which of the substances is a solid, a liquid and a gas?
   P = __________________; Q = __________________; R = ____________________

Figure 3 represents equal volumes of a very weak (or dilute) sugar solution and a very strong (or concentrated) sugar solution separated by a PERMEABLE MEMBRANE. Note that a permeable membrane allows all molecules to pass through it. Study the chart and use it to answer questions 9-12

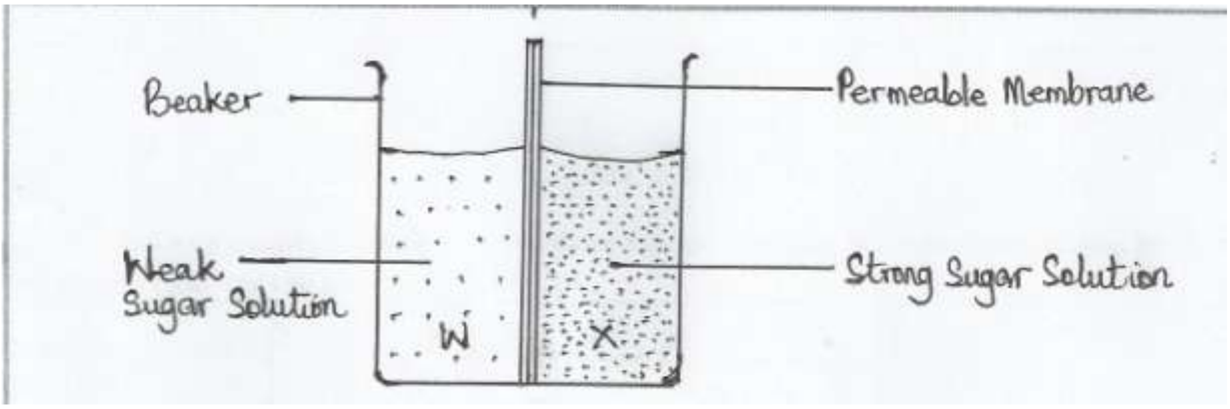


Figure 3: Equal volumes of weak and strong sugar solutions separated by a permeable membrane.

9. **OBS:** A concentration gradient exists between the ________________________ and _____________________ molecules in the weak and strong sugar solutions.
10. **MEA:** If the concentration of sugar molecules in W is $5g/dm^3$ and that in X is $20g/dm^3$, calculate the concentration gradient of sugar molecules in the system?

    ____

    ____

11. **PRD:** With the use of arrows only, indicate the net movement of sugar and water molecules across the permeable membrane in the chat below:

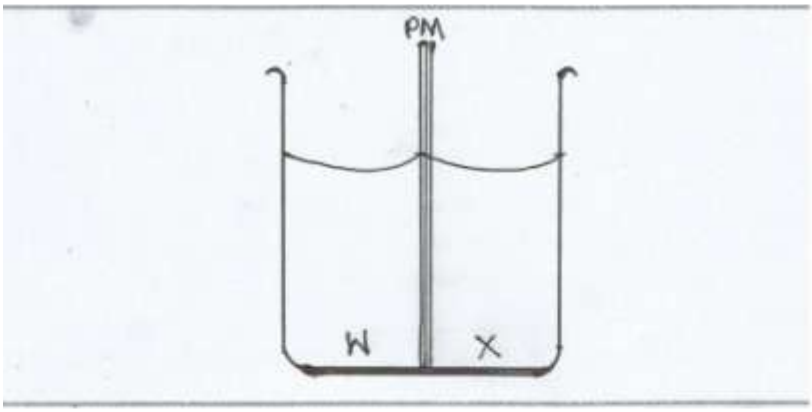
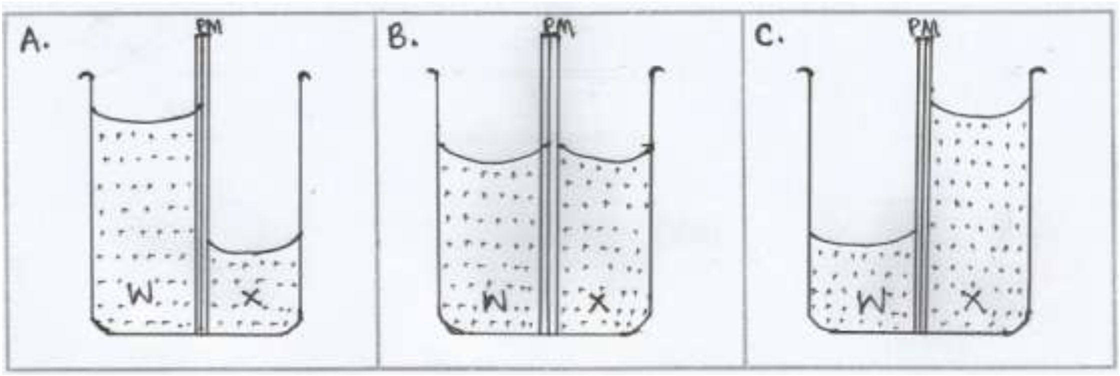


Figure 4: Movement of sugar and water molecules across the permeable membrane.

12. **COM:** Which of the following diagrams correctly represents the end result of the diffusion process when W is isotonic to X? *(Tick the right option)*



SECTION II

Figure 5 shows an experimental set-up to demonstrate Osmosis in a non-living tissue. Study the chart and use it to answer the questions 13 and 14.

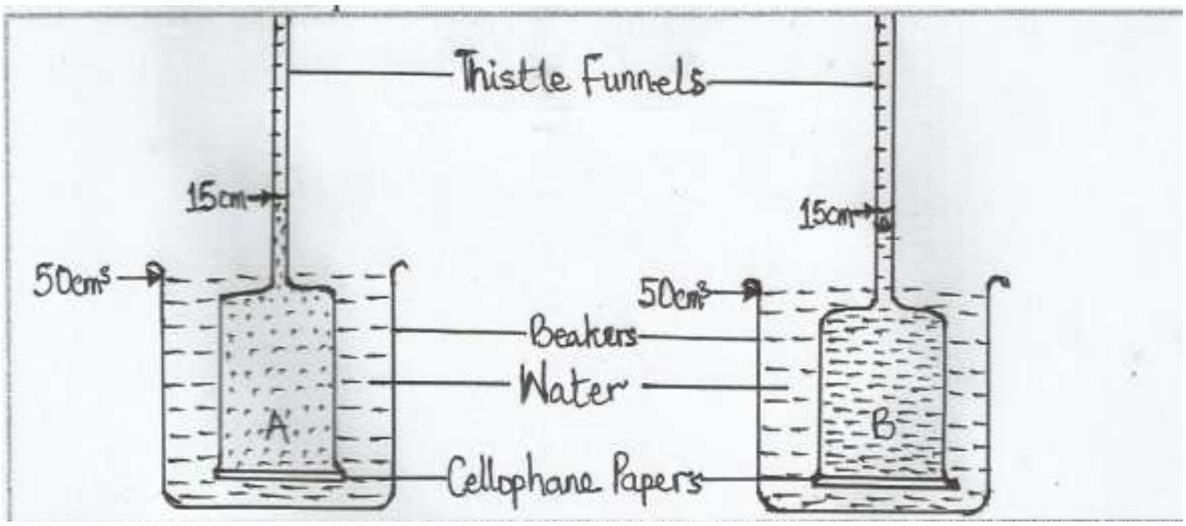


Figure 5: Experimental set-up to demonstrate Osmosis in a non-living tissue.

13. **INF:** When the experimental set-up was left for 20 minutes, the level of solution A rose to the 29cm mark while solution B remained on the 15cm mark. What can you infer from the above statement? ***(Tick as many true statements as possible)***

   a. Solution A is hypertonic to the water in the beaker.
   b. Solution A is hypotonic to the water in the beaker.
   c. Solution A is isotonic to the water in the beaker.
   d. Solution B is hypertonic to the water in the beaker.
   e. Solution B is hypotonic to the water in the beaker.
   f. Solution B is isotonic to the water in the beaker.

14. **MEA:** If the height of the solution is used to represent its concentration, find the concentration gradient between solution A and solution B. ______________________

____

Figure 6represents the heights risen by solution A in intervals of 5 minutes for 30 minutes as recorded by an SS2 student in a laboratory. Use the information to answer the questions 15-17.

Height (cm)	15	20	24	27	29	30	30
Time (Min)	0	5	10	15	20	25	30

Figure 6:Heights of solution 'A' recorded by a student in intervals of 5 minutes for 30 minutes.

15. Plot a graph of height against time.

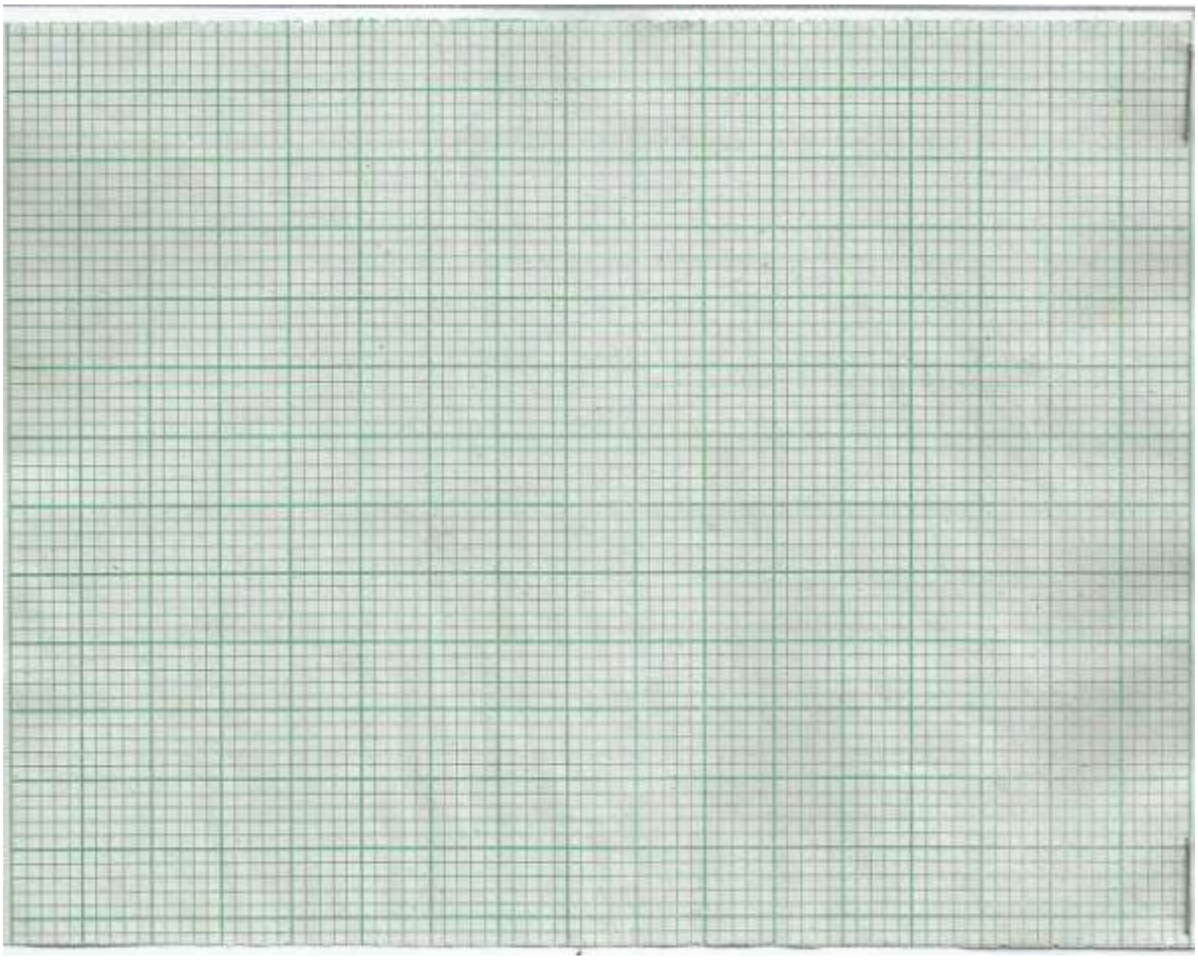


Figure 7:Graph of height risen by solution 'A' against time.

16. **INF:** What can you infer about the gradual decline in the height of solution A over time?

    ____

    ____

    ____

17. **PRD:** What do you think could happen after 50 minutes? *(Tick the right option)*
    a. Solution A will fall to the 25cm mark as water moves out of the thistle funnel.
    b. Solution A rises to the 50cm mark as water moves into the thistle funnel.
    c. There will be no rise or fall in the height of solution A as dynamic equilibrium has been achieved.

Figure 8 shows a beaker containing equal volumes of very weak (or dilute) sugar solution and very strong (or concentrated) sugar solution separated by a SEMI-PERMEABLE MEMBRANE. Note that a semi-permeable membrane only allows water molecules to pass through it. Study the chart carefully and use it to answer questions 18-20.

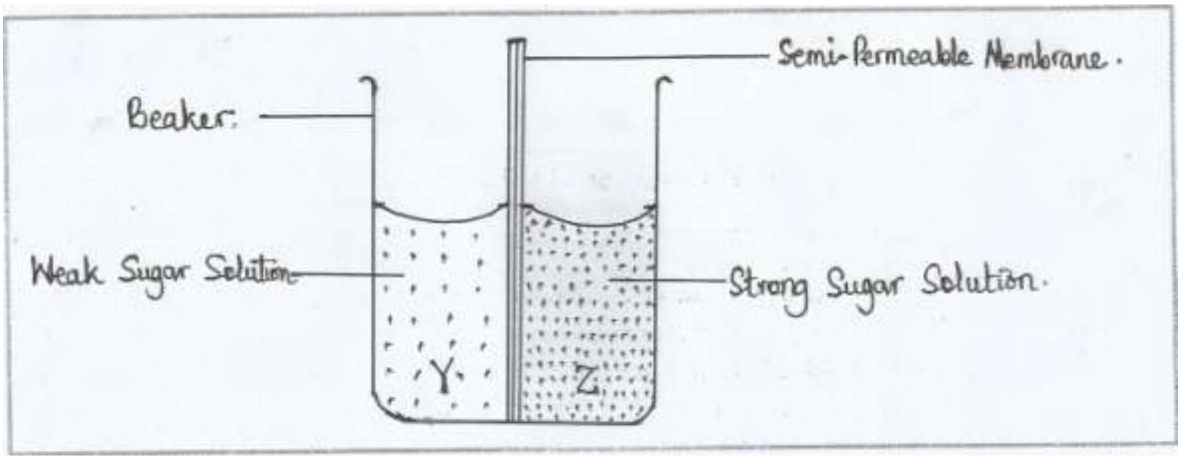


Figure 8: Equal volumes of weak and strong solutions separated by a semi-permeable membrane.

18. **OBS:** A concentration gradient exists between the ______________________________ and ________________________ molecules in the weak and strong sugar solutions.

19. **MEA:** If the concentration of solution Y is $8g/dm^3$ and that of solution Z is $33g/dm^3$ find the concentration gradient between solutions Y and Z. __________________ ____

20. **COM:** Draw a chart as in Figure 8 above to represent the possible levels of solutions Y and Z at dynamic equilibrium and use arrows to indicate t

Figure 9: Levels of solutions 'Y' and 'Z' at dynamic equilibrium.

SECTION III

Figure 10 represents the concentration of Sodium ions (Na^+) and Potassium ions (K^+) in the red blood cell and plasma. Study the chart carefully and use it to answer questions 21-24.

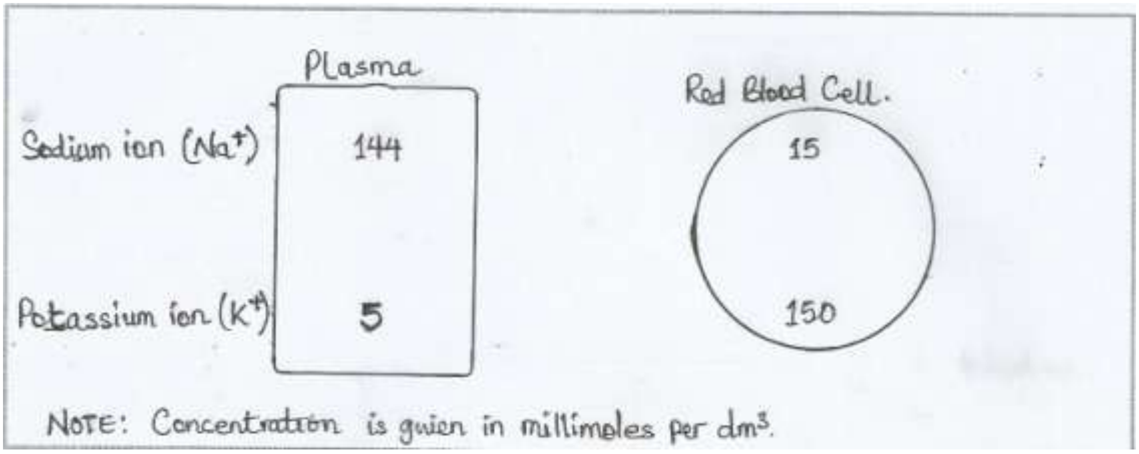


Figure 10: Transport of Sodium ions (Na^+) and Potassium ions (K^+) in the red blood cell and plasma.

21. **COM:** If active transport occurred, use arrows to indicate the direction of movement of Na^+ and K^+ ions between the plasma and red blood cell. ***(Do this on the chart in Figure 10 above)***.

22. **OBS:** Do the arrows indicate that Na^+ and K^+ are transported in accordance with or against their concentration gradients? ____

    ____

23. **INF:** Is energy required for this process to take place? **YES** [ ] or NO [ ]

24. **PRD:** What characteristics do you think the human red blood cells possess to enable it carry out this process efficiently? ***(Tick as much as are correct)***
    a. Numerous Mitochondria.
    b. Numerous Golgi apparatus.
    c. High concentration of ATP.
    d. Large Nucleus.
    e. High cellular respiratory rate.
    f. Ability to phagocyte ions.

SECTION IV

Figure 11 illustrates an experimental set-up wherein sugar is burnt in a hard glass tube and the products passed over white anhydrous Copper (II) sulphate and Lime water. Study the chart carefully and use it to answer questions 25-30.

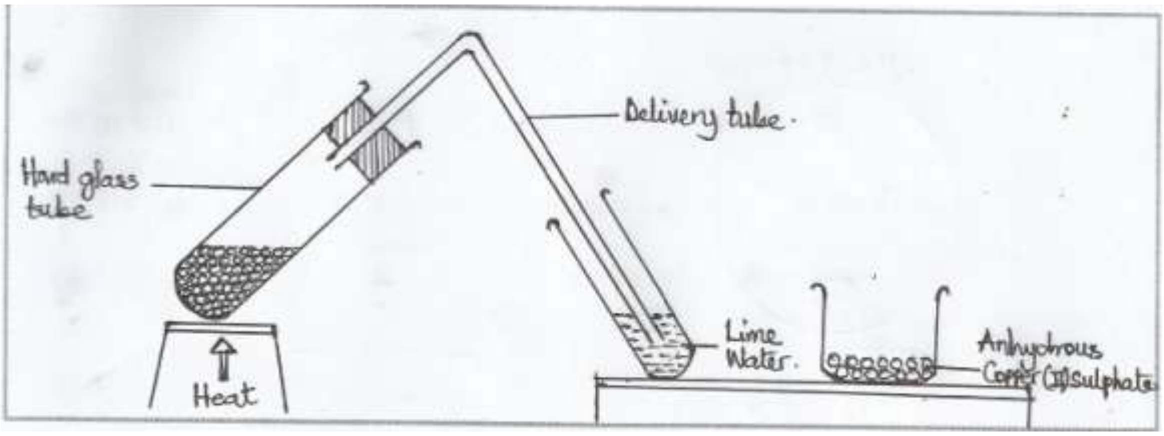


Figure 11: Experimental set-up to test for a food substance.

25. **OBS:** What do you observe after heating the sugar strongly for five minutes? ______

____

____

26. **OBS:** What happens to the white anhydrous $CuSO_4$ crystals? ____________

____

____

27. **INF:** What can you infer from the observation above? ________________

____

____

28. **OBS:** What happens to the colourless lime water? __________________

____

____

29. INF: What can you infer from that observation? __________________________

____

____

30. CLS i. Does sugar therefore qualify as a food substance? YES [ ] or NO [ ]

i. Why? ____

____

____

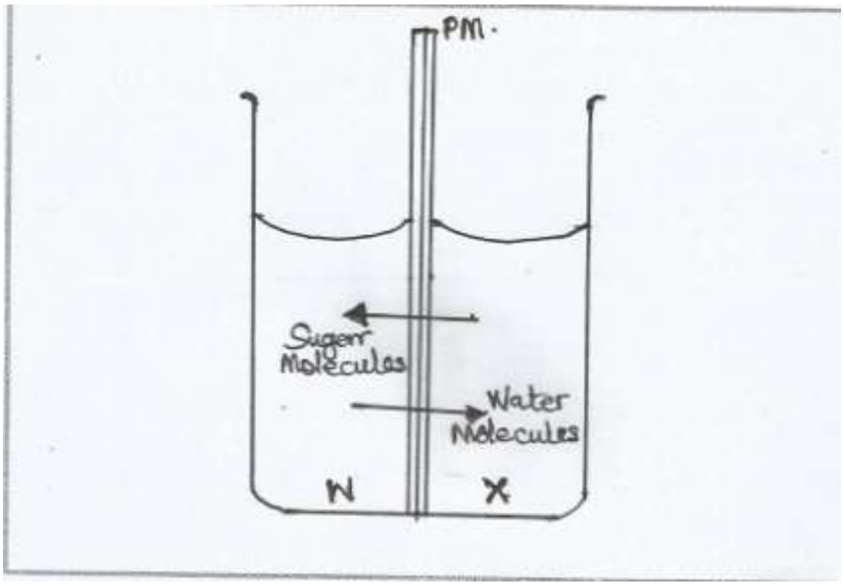
APPENDIX B

SCIENCE PROCESS-SKILLS ACQUISITION TEST (SPSAT)

MARKING SCHEME

SECTION I

1. i. Solid
   ii. Liquid
   iii. Gas **(1 mark each = 3 marks)**
2. The purple colour of $KMNO_4$ spreads throughout the water. **(= 2 marks)**
3. i. B **(1 mark)**
   ii. The diffusion of liquids is much faster than that of solids. **(2 marks)**
4. The rate of diffusion will increase and less time will be required for the process to come to completion. **(2 marks)**
5. C **(1 mark)**
6. The smell of the perfume spreads across the room. **(2 marks)**
7. i. C **(1 mark)**
   ii. The diffusion of gases is much faster than that of liquids. **(2 marks)**
8. P = Gas
   Q = Liquid
   R = Solid **(1 mark each = 3 marks)**
9. Sugar and Water **(2 marks)**
10. Concentration Gradient = $20g/dm^3 - 5g/dm^3 = 15g/dm^3$ (2 marks)
11.



(2 marks)

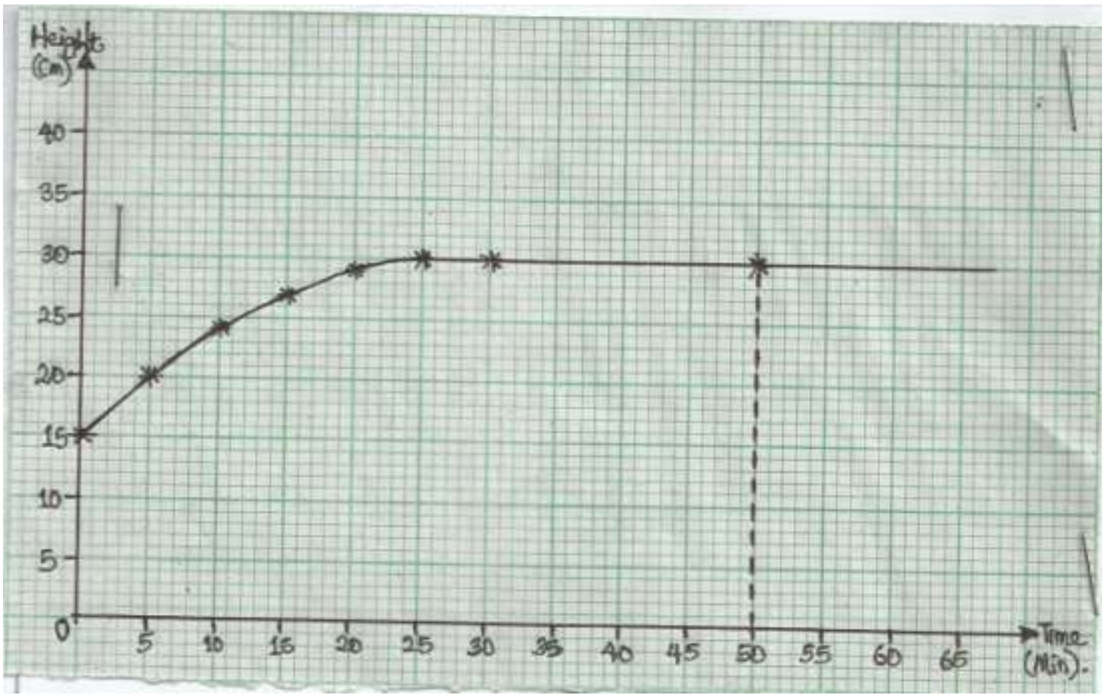
12. B **(1 mark)**

SECTION II

13. A and F **(2 marks)**

14. Concentration Gradient = 29cm - 15cm =14cm (2 marks)

15.



(7 marks)

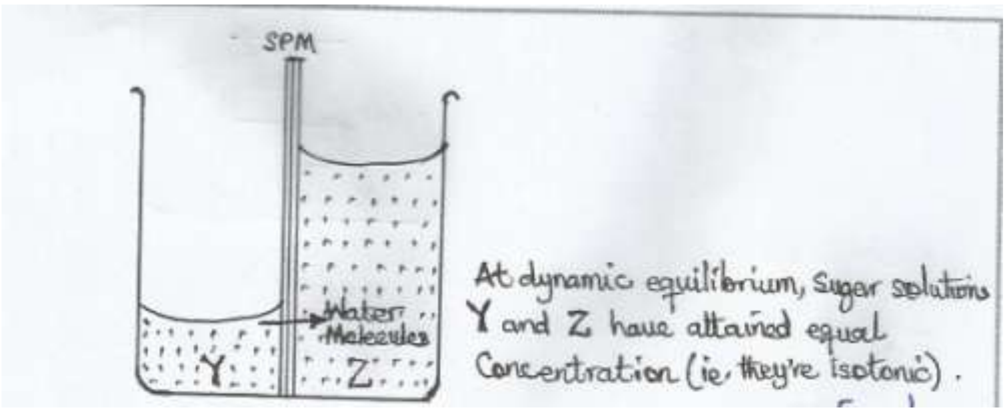
16. The rate of Osmosis is decreasing due to decrease in the concentration gradient. Therefore, as Osmosis takes place, the concentration of solution A decreases and the rate of movement of water molecules into the thistle funnel also reduces. **(2 marks)**

17. C **(1 mark)**

18. Sugar and Water. **(2 marks)**

19. Concentration Gradient = 33g/dm3 – $8g/dm^3$ $=25g/dm^3$ (2 marks)

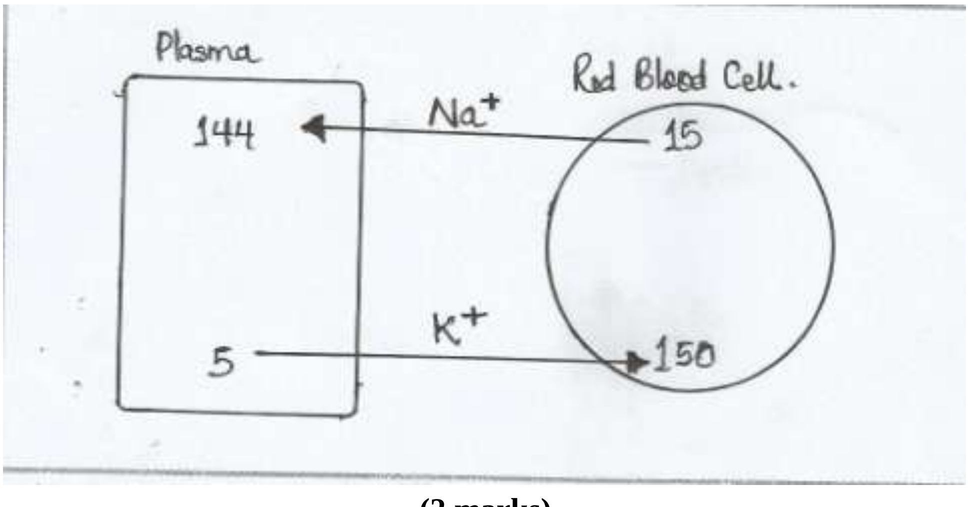
20.



(5 marks)

SECTION III

21.



(2 marks)

22. Na^+ and K^+ are transported against their concentration gradients. **(2 marks)**

23. Yes **(1 mark)**

24. A, C and E. **(3 marks)**

SECTION IV

25. Thick white fumes are produced. **(2 marks)**
26. The white anhydrous $CuSO_4$ crystals turn blue. (2 marks)
27. Water vapour is present in fumes. **(2 marks)**
28. Lime water turns milky or chalky. **(2 marks)**
29. Carbon dioxide is present in fumes. **(2 marks)**
30. i. Yes **(1 mark)**
    ii. Because just like every other food substance, sugar burns to produce Carbon dioxide and water vapour. **(2 marks)**

SECTION I	=	**26 marks**
SECTION II	=	**23 marks**
SECTION III	=	**8 marks**
SECTION IV	=	**13 marks**
TOTAL	=	**70 marks**

APPENDIX C

CELL PHYSIOLOGY PERFORMANCE TEST (CPPT)

Time allowed: 1 hour.

Instructions: Attempt all questions. Shade only the option on your answer sheet which corresponds to your chosen answer. An example has been done for you:

1. A B C D

DO NOT START UNTIL YOU ARE TOLD TO DO SO!

School Name: ____

Candidate's Number: ____________________ Gender: Male ☐ Female ☐

1. KNL: Which of the following best defines the term **diffusion**?
   a. The movement of only solute ions from the region of lower concentration to a region of higher concentration.
   b. The movement of molecules or ions from the region of lower concentration to a region of higher concentration.
   c. The movement of only water molecules from the region of higher concentration to a region of lower concentration.

   d. The movement of molecules or ions from the region of higher concentration to a region of lower concentration.

2. **KNL:** The difference in the concentration of a substance in the two regions that allows diffusion to take place is known as
   a. Osmotic Pressure
   b. Hypotonic solution
   c. Concentration gradient
   d. Hypertonic solution

3. **CMP:** Diffusion is important to flowering plants in the following ways ***except***
   a. Movement of carbon dioxide from lung capillaries into the air sac during respiration.
   b. Movement of oxygen into leaves through the stomata during respiration.
   c. Movement of carbon dioxide into the stomata of the leaves during photosynthesis.
   d. Movement of water vapour out of the leaves during transpiration.

4. **APL:** When Amoeba, Paramecium, Euglena and *Chlamydomonas* respire, they
   a. Exchange gases through their outer membranes by diffusion.
   b. Exchange gases through their cell walls by active transport.
   c. Exchange gases through their semi-permeable membranes by osmosis.
   d. Exchange gases through their plasma membranes by endocytosis.

5. **I - Differences in concentration**
   II - Presence of a semi-permeable membrane
   III - State of Matter
   IV - Presence of numerous mitochondria
   SYN: Which of the above mentioned factors does affect the rate of diffusion?
   a. I & II
   b. II & IV
   c. I & III
   d. II & III

6. **EVL:** Diffusion could be regarded as a life-sustaining process due to all the following ***except***
   a. It enables the embryo to take in nutrients and oxygen through the mother's placenta.
   b. It enables the movement of carbon dioxide through the stomata into the leaves of plants during photosynthesis.
   c. It allows for gaseous exchange in many cells and unicellular organisms.

d. It enables the spread of the smell of an insecticide sprayed from one part of a room.

7. **KNL:** When two solutions separated by a semi-permeable membrane have attained the same concentration, they are said to be
   a. Hypotonic
   b. Isotonic
   c. Hypertonic
   d. Equally tonic.

8. **KNL:** In living cells, stronger solutions apply a higher ________________ than weaker solutions
   a. Osmotic potential
   b. Osmotic strength
   c. Osmotic pressure
   d. Osmotic weakness

9. **CMP:** The following are conditions necessary for osmosis to take place *except*
   a. Presence of a freely permeable membrane.
   b. Presence of a weaker solution.
   c. Presence of a stronger solution.
   d. Presence of a selectively permeable membrane.

10. **APL:** Which of the following results when the fluid surrounding a living cell is more concentrated than the inside of the cell?
    a. There's a net movement of water molecules into the cell which causes it to swell.
    b. There's no net movement of water molecules into or out of the cell.
    c. The cell dies instantly and is replaced by a more concentrated cell.
    d. There's a net movement of water molecules out of the cell which causes it to shrink.

11. **ANL:** Which of the following is true about a red blood cell placed in a hypotonic solution?
    a. Cell absorbs plenty of water and become fully turgid.
    b. Cell loses water until its cytoplasm pulls away from the cell membrane.
    c. Cell loses water faster than it can absorb until it becomes flaccid.
    d. Cell absorbs plenty of water, become swollen and may even burst.

12. **EVL:** Which of the following can be considered to be most beneficial to land plants?

a. Flaccidity.
b. Haemolysis.
c. Turgidity.
d. Plasmolysis.

13. **KNL:** Transport of substances in and out of a cell against a concentration gradient with resultant energy consumption is called ____________________

a. Diffusion.
b. Osmosis.
c. Active transport.
d. Passive transport.

14. **KNL:** Endocytosis is best defined as

a. The movement of liquid materials into the cell with resultant loss of energy.
b. The process by which bulk materials are taken into the cell by vesicles with resultant energy consumption.
c. The movement of solid materials into the cell with no resultant loss of energy.
d. The process by which materials are transported out of the cell by vesicles with resultant energy consumption.

15. **KNL:** Hormones and enzymes are secreted from cells by reverse pinocytosis. This is an example of

a. Endocytosis.
b. Endosmosis.
c. Exosmosis.
d. Exocytosis.

16. **CMP:** The following are examples of active transport ***except***

a. Transport of water molecules into and out of the cell.
b. Transport of sodium ions out of the cells into the plasma.
c. Transport of potassium ions from the plasma into the cell.
d. Transport of chloride ions from the plasma into the cell.

17. **APL:** Which of the following transport mechanisms is most applicable to cells lining the gut where absorption of digested food substances occurs?

a. Exocytosis.
b. Active transport
c. Phagocytosis.
d. Passive transport.

18. **ANL:** Endocytosis can best be divided into _______________ and __________________

a. Endosmosis and exosmosis.
b. Active and passive transport.
c. Phagocytosis and Pinocytosis.
d. Osmosis and diffusion.

19. **I - Numerous mitochondria**
II - High rate of cellular respiration
III - High concentration of ATP
SYN: Which of the following are characteristics of cells carrying out active transport?
   a. I & III only.
   b. II & III only.
   c. I & II only.
   d. I, II & III.

20. **KNL:** Energy released during cellular respiration is stored as ____________________
   a. Adrenaline triphosphate.
   b. Adenosine tetraphosphate.
   c. Adenine triphosphate.
   d. Adenosine triphosphate.

21. **KNL:** The Kreb's Cycle takes place in the ________________ of all living cells.
   a. Mitochondria
   b. Endoplasmic reticulum
   c. Nucleus
   d. Cytoplasm

22. **CMP:** Which of the following equations best illustrates aerobic respiration?
   a. $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2 + \text{Energy}$
   b. $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + \text{Energy}$
   c. $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$
   d. $C_6H_{12}O_6 + 6CO_2 \rightarrow 6O_2 + 6H_2O + \text{Energy}$

23. **APL:** During vigorous exercise, the muscle cells do not get a sufficient supply of oxygen to meet their energy requirements. Which of the following occurs as a result?
   a. The muscle cells contract to cause permanent paralysis.
   b. Anaerobic respiration occurs to temporarily supply energy.
   c. Cellular respiration ceases and energy supply is cut off temporarily.
   d. Aerobic respiration occurs indefinitely.

24. **ANL:** In the early stage of cellular respiration, one molecule of 6-carbon glucose is broken down into ______________________________________.
   a. 2 molecules of 3-Carbon Citric acid.
   b. 3 molecules of 2-Carbon Lactic acid.
   c. 3 molecules of 2-Carbon Oxalic acid.
   d. 2 molecules of 3-Carbon Pyruvic acid.

25. **SYN:** Which of the following is ***not*** a similarity between aerobic and anaerobic respiration?
   a. Both occur in plant and animal cells.
   b. Oxygen is required for both to take place.
   c. Enzymes are required to speed up both reactions.
   d. Both lead to the release of energy in form of ATP.

26. **EVL:** Which of the following best represents the main purpose of cellular respiration in nature?
   a. To generate alcohol for the brewery industries.
   b. To generate heat and contribute to global warming.
   c. To generate carbon dioxide for photosynthesis in plants.
   d. To generate energy for various metabolic processes in organisms.

27. **KNL:** The building up of complex organic molecules from simple ones in a biological system is termed
   a. Anabolism.
   c. Catabolism.
   b. Glycolysis.
   d. Metabolism.

28. **KNL:** The cells in a leaf that contain large amount of chlorophyll for photosynthesis are called ______________________
   a. Lamina.
   c. Mid-rib.
   b. Stomata.
   d. Mesophyll.

29. **CMP:** Which of the following is not an example of an anabolic process?
   a. Formation of proteins from amino acids.
   b. Aerobic respiration in the body cells.
   c. Formation of starch from glucose.
   d. Photosynthesis in green plants.

30. **APL:** Which of the following is not a way in which the glucose manufactured during photosynthesis is used by plants?
   a. As a source of energy for their activities.
   b. For building up many organic molecules the plant needs.
   c. Converted to sucrose, starch and oils for storage.
   d. Used to enrich the soil as organic fertilizer.

31. **APL:** Photosynthesis is considered beneficial to the environment because
   a. It encourages the breeding of mosquitoes as the environment gets bushy.
   b. It adds to soil fertility by nitrogen fixation.

c. It purifies the atmosphere by adding Oxygen and removing Carbon dioxide.
d. It encourages bush burning when the plants dry out.

32. **ANL:** Which of the following equations best defines ***photolysis of water***?
a. $4H_2O \rightarrow 8H + 2O_2$
b. $4H_2O \rightarrow 4H_2 + 2O_2$
c. $4H_2O \rightarrow 3H_2O + OH$
d. $4H_2O \rightarrow 4H + 4OH$

33. **EVL:** Photosynthesis is considered the only means of sustaining life on earth because
a. Only through photosynthesis can the sun's enormous energy be tapped and converted to food for plants and animals on earth.
b. Only through photosynthesis can water be split into Hydrogen and Hydroxide ions.
c. Only through photosynthesis can Carbon dioxide be removed and Oxygen be supplied to the atmosphere.
d. Only through photosynthesis can plants grow to beautify the environment for man.

34. **KNL:** Mitosis generally takes place in the ____________________
a. Daughter cells.
b. Ovarian Cells.
c. Germ cells.
d. Somatic cells.

35. **KNL:** Meiosis is a form of cell division that results in ____________________________
a. Two daughter cells that are diploid.
b. Five daughter cells that are haploid.
c. Three daughter cells that are diploid.
d. Four daughter cells that are haploid.

36. **CMP:** Which of the following represents the correct sequence of phases in mitosis?
a. Anaphase, Telophase, Prophase, Metaphase and Interphase.
b. Metaphase, Interphase, Prophase, Anaphase and Telophase.
c. Interphase, Prophase, Metaphase, Anaphase and Telophase.
d. Prophase, Metaphase, Interphase, Anaphase and Telophase.

37. **CMP:** Mitotic process takes place in the following parts of plants ***except***in the _______.

a. Stem tip or apex.
b. Anthers and ovaries.
c. Root tip or apex.
d. Cambium in dicot stems.

38. **APL:** Which of the following is ***not*** an example of a mitotic process in animals?
   a. Formation of sperm cells in the testes.
   b. Healing of wound.
   c. Formation of new cells in the malphighian layer of skin.
   d. Production of blood cells in the bone marrow.

39. **APL:** Which of the following is ***not*** an application of meiosis in living systems?
   a. Formation of new cells in the liver of man.
   b. Formation of sperm cells in the testes of animals.
   c. Formation of pollen grains in the anthers of flowers.
   d. Formation of ova/eggs in the ovaries of man.

40. **ANL:** An amoeba (2n = 50) reproduces by binary fission. Which of the following correctly represents the number and nuclear composition of the offspring?
   a. Four (2n = 50) cells.
   b. Four (n = 25) cells.
   c. Two (2n = 50) cells.
   d. Two (n = 25) cells.

CPPT ANSWER SHEET.

1. A B C D
2. A B C D
3. A B C D
4. A B C D
5. A B C D
6. A B C D
7. A B C D
8. A B C D
9. A B C D
10. A B C D
11. A B C D
12. A B C D
13. A B C D
14. A B C D
15. A B C D
16. A B C D
17. A B C D
18. A B C D
19. A B C D
20. A B C D
21. A B C D
22. A B C D
23. A B C D
24. A B C D
25. A B C D

GUIDE: SHADE ONLY ONE OPTION.

26. A B C D
27. A B C D
28. A B C D
29. A B C D
30. A B C D
31. A B C D
32. A B C D
33. A B C D
34. A B C D
35. A B C D
36. A B C D
37. A B C D
38. A B C D
39. A B C D
40. A B C D
41. A B C D
42. A B C D
43. A B C D
44. A B C D
45. A B C D
46. A B C D
47. A B C D
48. A B C D
49. A B C D
50. A B C D

APPENDIX D

CELL PHYSIOLOGY PERFORMANCE TEST (CPPT)

MARKING SCHEME

1.	D	21.	A
2.	C	22.	C
3.	A	23.	B
4.	A	24.	D
5.	C	25.	B
6.	D	26.	D
7.	B	27.	A
8.	C	28.	D
9.	A	29.	B
10.	D	30.	D
11.	D	31.	C
12.	C	32.	D
13.	C	33.	A
14.	B	34.	D
15.	D	35.	D
16.	A	36.	C
17.	B	37.	B
18.	C	38.	A
19.	D	39.	A
20.	D	40.	C

1 mark each

Total = 40 marks.

APPENDIX F

ITEM ANALYSIS

ITEM	FACILITY INDEX (F.I.)	DISCRIMINATION INDEX (D.I.)	REMARK
1	0.57	0.43	Accepted
2	0.46	0.36	Accepted
3	0.36	0.14**	Rejected
4	0.39	0.36	Accepted
5	0.43	0.43	Accepted
6	0.32	0.07**	Rejected
7	0.39	0.64	Accepted
8	0.54	0.64	Accepted
9	0.43	-0.14**	Rejected
10	0.46	0.50	Accepted
11	0.57	0.57	Accepted
12	0.32	0.36	Accepted
13	0.32	0.64	Accepted
14	0.39	0.21*	Modified
15	0.18**	-0.07**	Rejected
16	0.46	0.50	Accepted
17	0.36	0.43	Accepted
18	0.68	0.50	Accepted
19	0.54	0.36	Accepted
20	0.50	-0.14**	Rejected
21	0.43	0.29*	Modified
22	0.39	0.36	Accepted
23	0.46	0.50	Accepted
24	0.54	0.21	Modified
25	0.14**	0.14**	Rejected
26	0.25*	0.50	Modified
27	0.61	0.36	Accepted
28	0.21*	-0.14**	Rejected
29	0.32	0.50	Accepted
30	0.29*	0.43	Modified
31	0.54	0.64	Accepted
32	0.39	0.64	Accepted
33	0.39	0.50	Accepted
34	0.57	0.57	Accepted
35	0.57	0.43	Accepted
36	0.54	0.36	Accepted
37	0.39	0.36	Accepted
38	0.25*	0.36	Modified
39	0.57	0.29*	Modified

40	0.18**	0.36	Rejected
41	0.39	0.64	Accepted
42	0.43	0.57	Accepted
43	0.50	0.57	Accepted
44	0.46	0.64	Accepted
45	0.36	0.29*	Modified
46	0.43	0.43	Accepted
47	0.50	0.43	Accepted
48	0.32	0.21*	Modified
49	0.32	-0.07**	Rejected
50	0.29*	0.00**	Rejected

KEY FOR F.I.:

0.81 - 1.00 → Very Easy → Rejected

0.71 - 0.80 → Easy → Modified

0.30 - 0.70 → Moderate → Accepted

0.20 - 0.29 → Difficult → Modified

0.00 - 0.19 → Very Difficult → Rejected

KEY FOR D.I.:

(-1.00) - (-0.01) → Negative Values → Rejected

0.00 → No Discrimination → Rejected

0.01 - 0.19 → Very Low Positive Values → Rejected

0.20 - 0.29 → Low Positive Values → Modified

0.30 - 0.70 → Moderately Positive Values → Accepted

0.71 - 0.80 → High Positive Values → Modified

0.81 - 1.00 → Very High Positive Values → Rejected

APPENDIX G

TEST-RETEST RELIABILITY OF SPSAT

```
CORRELATIONS
  /VARIABLES=SPSAT_1 SPSAT_2
  /PRINT=TWOTAIL NOSIG
  /STATISTICS DESCRIPTIVES
  /MISSING=PAIRWISE.
```

Correlations

[DataSet0]

Descriptive Statistics

	Mean	Std. Deviation	N
SPSAT_1	18.44	7.054	50
SPSAT_2	20.56	7.451	50

Correlations

		SPSAT_1	SPSAT_2
SPSAT_1	Pearson Correlation	1	.842**
	Sig. (2-tailed)		.000
	N	50	50
SPSAT_2	Pearson Correlation	.842**	1
	Sig. (2-tailed)	.000	
	N	50	50

**. Correlation is significant at the 0.01 level (2-tailed).

NB: The correlation coefficient (r = 0.84) indicates a strong positive correlation between the students' scores in the first and second SPSAT administrations. Hence, SPSAT has a strong coefficient of stability and is therefore reliable for use in the study.

APPENDIX H

SPLIT-HALF RELIABILITY OF SPSAT

```
NONPAR CORR
  /VARIABLES=SPSAT_OddSPSAT_Even
  /PRINT=SPEARMAN TWOTAIL NOSIG
  /MISSING=PAIRWISE.
```

Descriptive Statistics

	Mean	Std. Deviation	N
SPSAT_Odd	9.74	4.115	50
SPSAT_Even	8.70	3.284	50

Correlations

			SPSAT_Odd	SPSAT_Even
Spearman's rho	SPSAT_Odd	Correlation Coefficient	1.000	.790**
		Sig. (2-tailed)	.	.000
		N	50	50
	SPSAT_Even	Correlation Coefficient	.790**	1.000
		Sig. (2-tailed)	.000	.
		N	50	50

**. Correlation is significant at the 0.01 level (2-tailed).

Spearman-Brown Formula

$$r½½ = \frac{2r½}{1 + r½}$$

Where r½ = Reliability of a half test

Therefore, $r½½ = \frac{2*0.79}{1+0.79}$ = 1.58/1.79 = 0.8827

NB: The Spearman-Brown coefficient (r = 0.88) indicates a strong positive correlation between the students' scores in the odd and even halves of SPSAT. Hence, SPSAT has a strong coefficient of internal consistency and is therefore reliable for use in thestudy.

APPENDIX I

TEST-RETEST RELIABILITY OF CPPT

```
CORRELATIONS
  /VARIABLES=CPPT_1 CPPT_2
  /PRINT=TWOTAIL NOSIG
  /STATISTICS DESCRIPTIVES
  /MISSING=PAIRWISE.
```

Correlations

[DataSet0]

Descriptive Statistics

	Mean	Std. Deviation	N
CPPT_1	14.26	4.203	50
CPPT_2	15.64	4.776	50

Correlations

		CPPT_1	CPPT_2
CPPT_1	Pearson Correlation	1	.888**
	Sig. (2-tailed)		.000
	N	50	50
CPPT_2	Pearson Correlation	.888**	1
	Sig. (2-tailed)	.000	
	N	50	50

**. Correlation is significant at the 0.01 level (2-tailed).

NB: The correlation coefficient (r = 0.89) indicates a strong positive correlation between the students' scores in the first and second CPPT administrations. Hence, CPPT has a strong coefficient of stability and is therefore reliable for use in the study.

APPENDIX J

TABLES FOR ANOVA AND SCHEFFE'S POST HOC TEST

```
ONEWAY SPSAT_PretestCPPT_Pretest BY School
  /STATISTICS DESCRIPTIVES
  /MISSING ANALYSIS
  /POSTHOC=SCHEFFE ALPHA(0.05).
```

Oneway

Descriptives

		N	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
						Lower Bound	Upper Bound		
SPSAT_Pretest	GSS Dakace	75	24.04	5.135	.593	22.86	25.22	14	33
	GSS Likoro	54	21.06	4.465	.608	19.84	22.27	13	30
	GSS Kugu	84	17.43	4.192	.457	16.52	18.34	9	28
	GSS Yakasai	56	20.61	4.758	.636	19.33	21.88	12	33
	Total	269	20.66	5.274	.322	20.03	21.29	9	33
CPPT_Pretest	GSS Dakace	75	14.87	3.520	.406	14.06	15.68	9	23
	GSS Likoro	54	13.13	3.603	.490	12.15	14.11	7	22
	GSS Kugu	84	10.86	2.584	.282	10.30	11.42	5	16
	GSS Yakasai	56	12.84	3.846	.514	11.81	13.87	7	22
	Total	269	12.84	3.673	.224	12.40	13.28	5	23

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SPSAT_Pretest	Between Groups	1742.574	3	580.858	26.950	.000
	Within Groups	5711.642	265	21.553		
	Total	7454.216	268			
CPPT_Pretest	Between Groups	642.844	3	214.281	19.103	.000
	Within Groups	2972.599	265	11.217		
	Total	3615.442	268			

Post Hoc Tests

Multiple Comparisons

Scheffe

Dependent Variable	(I) School	(J) School	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
SPSAT_Pretest	GSS Dakace	GSS Likoro	2.984*	.829	.005	.65	5.32
		GSS Kugu	6.611*	.738	.000	4.54	8.69
		GSS Yakasai	3.433*	.820	.001	1.13	5.74
	GSS Likoro	GSS Dakace	-2.984*	.829	.005	-5.32	-.65
		GSS Kugu	3.627*	.810	.000	1.35	5.91
		GSS Yakasai	.448	.885	.968	-2.04	2.94
	GSS Kugu	GSS Dakace	-6.611*	.738	.000	-8.69	-4.54
		GSS Likoro	-3.627*	.810	.000	-5.91	-1.35
		GSS Yakasai	-3.179*	.801	.002	-5.43	-.93
	GSS Yakasai	GSS Dakace	-3.433*	.820	.001	-5.74	-1.13
		GSS Likoro	-.448	.885	.968	-2.94	2.04
		GSS Kugu	3.179*	.801	.002	.93	5.43
CPPT_Pretest	GSS Dakace	GSS Likoro	1.737*	.598	.040	.06	3.42
		GSS Kugu	4.010*	.532	.000	2.51	5.51
		GSS Yakasai	2.027*	.592	.009	.36	3.69
	GSS Likoro	GSS Dakace	-1.737*	.598	.040	-3.42	-.06
		GSS Kugu	2.272*	.584	.002	.63	3.92
		GSS Yakasai	.290	.639	.976	-1.51	2.09
	GSS	GSS Dakace	-4.010*	.532	.000	-5.51	-2.51

	Kugu	GSS Likoro	-2.272*	.584	.002	-3.92	-.63
		GSS Yakasai	-1.982*	.578	.009	-3.61	-.36
	GSS Yakasai	GSS Dakace	-2.027*	.592	.009	-3.69	-.36
		GSS Likoro	-.290	.639	.976	-2.09	1.51
		GSS Kugu	1.982*	.578	.009	.36	3.61

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

SPSAT_Pretest

Scheffe

School	N	Subset for alpha = 0.05		
		1	2	3
GSS Kugu	84	17.43		
GSS Yakasai	56		20.61	
GSS Likoro	54		21.06	
GSS Dakace	75			24.04
Sig.		1.000	.959	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 64.921.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

CPPT_Pretest

Scheffe

School	N	Subset for alpha = 0.05		
		1	2	3
GSS Kugu	84	10.86		
GSS Yakasai	56		12.84	
GSS Likoro	54		13.13	
GSS Dakace	75			14.87
Sig.		1.000	.970	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 64.921.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

APPENDIX K

5Es INSTRUCTIONAL PACKAGE (5-EIP)

WEEK ONE

Method of Teaching: 5Es Instructional Strategy

Subject: Biology

Group: Experimental

Class: SS II

Number of Students: 54

Topic: Diffusion and Its Applications in Living and Non-Living Systems

Duration: 80 minutes (Double Period)

Reference Materials: Maxwell, D.A. (1998). *New Practical Biology for Senior Secondary Schools*. Ibadan: ONIBONOJE Press - Publishers.

Michael, M.C. (2015). *Essential Biology for Senior Secondary Schools.* Ikeja: TONAD Publishers Limited.

Ramalingam, S.T. (2010). *Modern Biology for Senior Secondary Schools.* Onitsha: Africana First Publishers Plc.

Instructional Materials: Potassium permanganate crystals, room freshener, beakers, water, charts illustrating diffusion through a permeable membrane, students' worksheet.

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

i. define diffusion correctly in their own words;
ii. explain briefly at least three factors that affect the rate of diffusion;
iii. perform at least one experiment to demonstrate the process of diffusion in non-living systems;
iv. mention at least two importance each of diffusion to plants and animals;
v. outline at least three applications of diffusion in non-living conditions;
vi. demonstrate perseverance and objectivity as they carry out experiments; and
vii. display humility and open-mindedness as they work with their peers to solve problems.

Previous Knowledge: Students are:

- familiar with the fact that matter is made up of tiny particles such as molecules or ions which are constantly moving and can exist in three states - solid, liquid and gas;
- aware of the fact that any substance can exist as a solid, a liquid or a gas depending on the conditions of temperature and pressure it is subjected to;
- conversant with the use of perfumes, room fresheners and dyes.

Presentation: Teacher organizes students into 9 groups of 6 students each, highlights the topic to be learnt and emphasizes the need for each student to participate fully in classroom activities.

Phase 1: ENGAGEMENT

Teacher uses probing questions related to students' previous knowledge to capture students' attention and interest to the topic. i.e.:

i. What is matter?
ii. What are the states of matter?
iii. What are the basic components of all matter?
iv. What are the characteristics of each of the different forms of matter?
v. Do liquids flow faster than gases? Why?

Phase 2: EXPLORATION

Teacher presents two activities to be carried out by students and use certain conceptual questions to encourage and focus students' exploration. i.e.:

ACTIVITY 1

Aim: To Demonstrate Diffusion in Solids.

Materials: Potassium permanganate crystal, beaker, water, record sheet.

Procedure: Place a crystal of Potassium permanganate in a beaker of water and leave it to stand. Observe and record what happens after 1minute, 3minutes and 5minutes respectively.

Conceptual Questions:

i. What are your explanations for the observations?
ii. What could happen if the mixture is heated or if hot water is used?
iii. Why was the mixture not stirred, tilted or shaken?

iv. What do you think would happen if the potassium permanganate solution is used instead of the solid crystals?

ACTIVITY 2

Aim: To Demonstrate Diffusion in Gases.

Materials: Room freshener, record sheet.

Procedure: Spray a little amount of room freshener in one corner of the classroom.

Observe and record what happens after 1minute, 3minutes and 5minutes respectively.

Conceptual Questions:

i. What are your explanations for the observations?
ii. What could happen if the perfume is sprayed while the classroom windows and doors were all closed?
iii. What do you think would happen if the perfume is sprayed on a very windy day and the windows and doors are all open?

Phase 3: EXPLANATION

Teacher solicits students' explanations regarding certain keywords and phenomena as it relates to their exploration and helps them justify their explanations. i.e.:

i. What do you understand by the word 'diffusion'?
ii. In what ways do you think diffusion rate can be increased?
iii. Of what importance is diffusion to plants and animals?
iv. How does diffusion apply in non-living conditions?

Teacher also provides explanations of concepts and phenomena related to the topic in a direct and formal manner. i.e.:

Meaning of Diffusion

Diffusion is defined as the process by which molecules or ions of a substance (i.e.gases and liquids) move from a region of high concentration to a region of low concentration until they are evenly distributed. The substance involved in diffusion may be liquid, gases or solid.

Factors Affecting the Rate of Diffusion

The rate or speed of diffusion is controlled by a number of factors which include:

(1) **State of Matter**: Diffusion varies with the three states of matter. The diffusion of gases is much faster than that of liquids because the gas molecules are freer and therefore faster than liquid molecules.
(2) **Molecular Size**. The nature or the size of the molecules affects diffusion. In general, the smaller the molecules, the faster the rate of diffusion while the larger the molecules, the slower the rate of diffusion.
(3) **Differences in concentration**: For diffusion to take place in a medium, there must be differences in the concentration of the substance in two areas. This difference is known as the **concentration or diffusion gradient**. The greater the difference in the concentration of the molecules, the greater the rate of diffusion.
(4) **Temperature**: High temperature increases the speed at which molecules move. Thus, the higher the temperature, the faster the rate of diffusion.

Importance of Diffusion to Animals

Diffusion plays important roles in the life of animals through the following processes:

(a) There is intake of oxygen or nutrients from mother to foetus (embryo) through placenta.
(b) Gaseous exchange in mammals occurs in the lungs during respiration.
(c) Gaseous exchange in many cells and organisms, e.g. Amoeba takes in oxygen and gets rid of carbon dioxide by diffusion.
(d) There is movement of carbon dioxide from the lung capillaries into the air sac.

Importance of Diffusion to Plants

Diffusion is important to flowering plants in the following ways:

(a) Movement of carbon dioxide through the stomata of the leaves during respiration.
(b) There is movement of carbon dioxide through the stomata into the leaves during photosynthesis.
(c) Water vapour leaving the leaves during transpiration.
(d) Movement of oxygen into the leaves through the stomata during respiration.

Applications of Diffusion in Non-Living Conditions

Diffusion is also very important in nature or non-living conditions through the following processes:

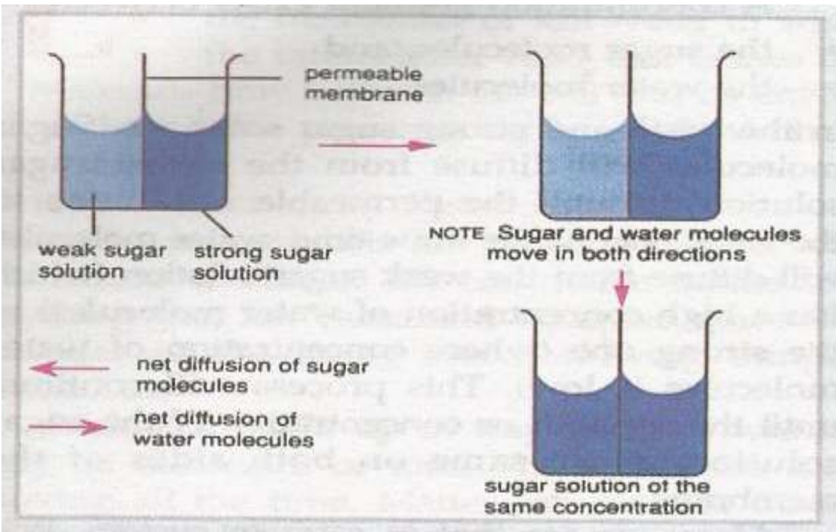
(a) The spread of the smell or odour of perfume from a person or a corner of a room;
(b) Diffusion of molecules (gases and liquid) in iodine, potassium permanganate and copper sulphate solutions;
(c) The spread of insecticide in a room;
(d) The spread of the smell of gases released from the anus.

Phase 4: ELABORATION

Teacher extends students' understanding of the concept by presenting further activities. i.e.:

ACTIVITY 3

Aim: To Demonstrate Diffusion through a Permeable Membrane.
Materials: Charts illustrating diffusion through a permeable membrane.
Procedure: Equal volumes of very weak (dilute) sugar solution and a strong (concentrated) sugar solution are separated by a **permeable membrane** as illustrated in the chart before you. **Note that a permeable membrane** allows **all molecules to pass through it.**



Study the chart as a group and attempt the questions that follow.

Conceptual Questions:

1. A concentration gradient exists between:
   a. ____
   b. ____
2. What are the possible conclusions regarding the movement of sugar and water molecules?
   a. ____
   b. ____
3. At the end of the experiment, the strength or concentration of the sugar solution is the same on both sides of the membrane and the system is said to be in DYNAMIC EQUILIBRIUM. What does this mean in relation to the movement of sugar and water molecules?
   a. ____
4. From the experiment, is it right to conclude thatin a given system:
   a. It is possible for the diffusion of different types of molecules or ions to be in different directions at the same time? [YES / NO].
   b. Each type of molecule or ion move at its own rate according to its concentration gradient? [YES / NO].

Phase 5: EVALUATION

Teacher ensures that students demonstrate their achievement of the lesson

objectives by asking them the following questions:

i. Define diffusion in your own words.

ii. Briefly explain any three factors that affect the rate of diffusion.
iii. Describe any one experiment to show the process of diffusion in non-living systems.
iv. Mention two importance each of diffusion to plants and animals.
v. Outline three applications of diffusion in non-living conditions.

WEEK TWO

Method of Teaching: 5Es Instructional Strategy

Subject: Biology

Group: Experimental

Class: SS II

Number of Students: 54

Topic: Osmosis and Its Applications in Living and Non-Living Systems

Duration: 80 minutes (Double Period)

Reference Materials: Maxwell, D.A. (1998). *New Practical Biology for Senior Secondary Schools*. Ibadan: ONIBONOJE Press - Publishers.

Michael, M.C. (2015). *Essential Biology for Senior Secondary Schools.* Ikeja: TONAD Publishers Limited.

Ramalingam, S.T. (2010). *Modern Biology for Senior Secondary Schools.* Onitsha: Africana First Publishers Plc.

Instructional Materials: Thistle funnel, water, sugar solution, cellophane paper, peeled yam tuber, glass tubing, stopper, retort stand, charts showing osmosis through a semi-permeable membrane, charts showing the effects of solutions of different strengths on red blood cells, charts showing the effects of water and sugar solution on onion cells, students' worksheet.

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

i. define osmosis correctly in their own words;
ii. differentiate between a hypotonic, a hypertonic and an isotonic solution;
iii. distinguish between endosmosis and exosmosis;
iv. perform an experiment to demonstrate the process of osmosis in non-living systems;
v. perform an experiment to demonstrate the process of osmosis in a living tissue;
vi. explain briefly the terms osmotic pressure, osmotic potential, haemolysis, plasmolysis, turgidity and flaccidity;
vii. draw diagrams to illustrate the effects of solutions of different strengths on animal cells;
viii. draw diagrams to illustrate the effects of solutions of different strengths on plant cells;
ix. demonstrate perseverance and objectivity as they carry out experiments; and
x. display humility and open-mindedness as they work with their peers to solve problems.

Previous Knowledge: Students are:

- familiar with the concept of diffusion wherein ions or molecules of a substance move from a region where they are more concentrated to a region where they are less concentrated;
- aware of the fact that water molecules can move freely through a permeable membrane in directions and quantities that depend on the concentration gradient.

Presentation: Teacher organizes students into 9 groups of 6 students each, highlights the topic to be learnt and emphasizes the need for each student to participate fully in classroom activities.

Phase 1: ENGAGEMENT

Teacher uses probing questions related to students' previous knowledge to capture students' attention and interest to the topic. i.e.:

i. What is diffusion?
ii. What factors affect the rate of diffusion?
iii. What are the basic conditions of diffusion?
iv. Is energy generated or used up in the process of diffusion?

Phase 2: EXPLORATION

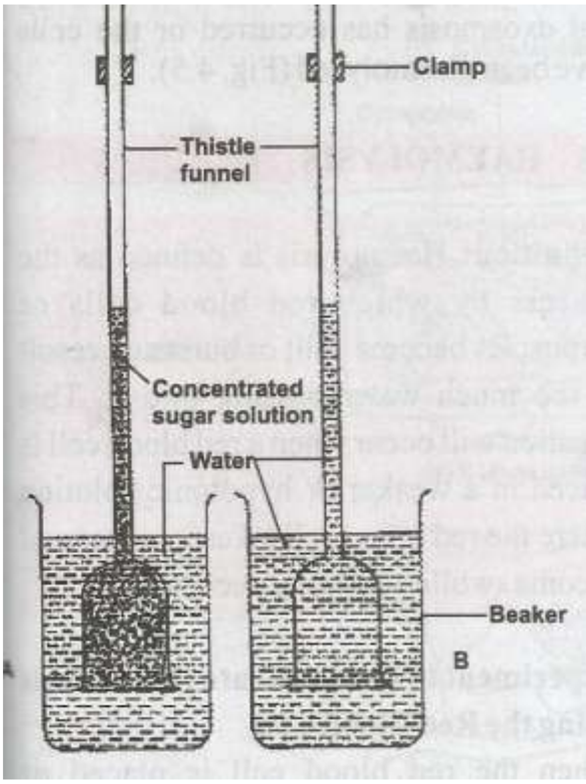
Teacher presents two activities to be carried out by students and use certain conceptual questions to encourage and focus students' exploration. i.e.:

ACTIVITY 1

Aim: To Demonstrate Osmosis in a Non-living System.

Materials: Thistle funnels, cellophane papers, beakers, water, concentrated sugar solution, retort stands, record sheet.

Procedure: Pour equal quantity of water into the beakers then cover the bottom of the thistle funnels with cellophane paper (the selectively permeable membrane). Pour some concentrated sugar solution into the thistle funnel A and water into thistle funnel B (control experiment) and mark their levels. Then, immerse the two funnels into the beakers containing water and support each with a retort stand as illustrated in the chart below:



Conceptual Questions:

i. Record the height of the sugar solution at 5-minutes intervals for 20 minutes.
ii. Plot the graph of height risen by sugar solution against time.
iii. What are the possible reasons for the rise in the level of sugar solution?
iv. What do you think will happen to the concentration and volume of the sugar solution after three hours?
v. How do you think the graph will look after three hours?

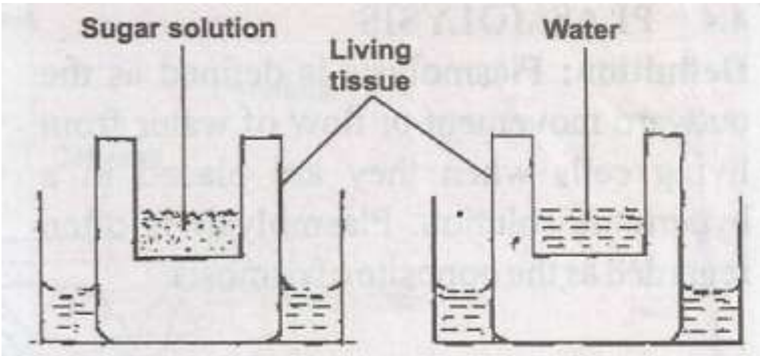
ACTIVITY 2

Aim: To Demonstrate Osmosis in a Living Tissue.

Materials: Yam tuber, sugar solution, water, knife, wide beakers, record sheet.

Procedure: Peel the yam tuber, cut it into two parts and make a cavity with the aid of the knife into the two cut yam tubers. Pour water into the two beakers and place each half of the yam tubers with base down into the beakers containing water.

Add a small quantity of sugar solution to yam tissue A and allow yam tissue B to serve as control experiment by adding the same quantity of water to it. Leave for 5 hours. Set up the experiment as illustrated in the chart below. Meanwhile, attempt these questions about the experiment.



Conceptual Questions:

i. What do you think would happen to the level of sugar solution in A? Why?
ii. What do you think would happen to the level of water in B? Why?
iii. What do you think would happen to the level of water in beaker A? Why?
iv. What do you think would happen to the level of water in beaker B? Why?

Phase 3: EXPLANATION

Teacher solicits students' explanations regarding certain keywords and phenomena as it relates to their exploration and helps them justify their explanations. i.e.:

i. What do you understand by the word 'osmosis"?
ii. Differentiate between hypotonic, hypertonic and isotonic solutions?
iii. Distinguish between endosmosis and exosmosis.

Teacher also provides explanations of concepts and phenomena related to the topic in a direct and formal manner. i.e.:

Meaning of Osmosis

Osmosis is defined as the flow of water or solvent molecules from a region of dilute or weaker solution to a region of concentrated or stronger solution through a selectively or differentially permeable membrane. It should be noted that osmosis is a special form of diffusion.

Conditions Necessary for Osmosis to Occur

There are three major conditions which are necessary for osmosis to take place. These are:

(a) Presence of a stronger solution, e.g. sugar or salt solution;
(b) Presence of a weaker solution, e.g. distilled water;
(c) Presence of a selectively or differentially permeable membrane.

Living Cells as Osmometer

In osmosis, there are usually two solutions which are separated by a differentially permeable membrane. The weaker solution is said to be **hypotonic** while the stronger solution is said to be **hypertonic**. When both solutions have the same concentration, they are said to be **isotonic**. In living cells, when water moves across the membrane into a solution of a higher concentration, a pressure is created in the cell. This pressure is called **osmotic pressure**. The solution is said to exert a higher osmotic pressure than the weaker solution. Osmotic pressure is a force that draws in water into the cell. The pressure which a solution can potentially exert is called its **osmotic potential**. Osmoregulation is the control of fluctuations in the concentration of substances in cell fluids by special devices such as the contractile vacuoles in Amoeba and paramecium.

Cells and Osmosis

A living cell is bound by a plasma membrane. This membrane is **selectively permeable** and allows water and certain solute molecules and ions to pass through it. As a result, the plasma membrane regulates the movement of materials between the cell and its environment. In contrast, a **semi-permeable** membrane only allows water molecules to pass through it.

Osmosis in Animal Cells (with diagram)

Animal cells contain mainly cytoplasm and cell organelles. In higher animals, the cells are bathed in intercellular fluid or plasma. The concentration of the solutes in these fluids is important for the well-being and functioning of the cells.

A living cell may find itself in any of the following situations:

- The fluid surrounding the cell is more concentrated than the inside of the cell. In this case, the surrounding fluid is said to be **hypertonic** to the contents of the cell. There is a net movement of water of molecules out of the cell into the surrounding. This is known as **exosmosis**. It causes the cell to shrink.
- The fluid surrounding the cell is less concentrated than the inside of the cell. Here, the surrounding fluid is said to be **hypotonic** to the contents of the cell. There is a net movement of water molecules from the surrounding fluid into the cell. This is known as **endosmosis**. It causes the cell to swell, and eventually rupture.
- The surrounding fluid and the cell contents have the same concentration. Hence, they are said to be **isotonic**. There is no net movement of water molecules in or out of the cell.

To survive and function well, the living cell and the fluid that bathes it must be **isotonic** or be able to maintain an **osmotic balance**. **Endosmosis**and **exosmosis**can lead to the eventual death of an animal.

Osmosis in Plant Cells (with diagram)

Plant cells have cell membranes and cell walls. The cell wall is a tough and fairly elastic structure that is **freely permeable** to all molecules and ions. The cell membrane, however, is **selectively permeable**. Unlike an animal, most of the space in a plant cell is occupied by a large central vacuole that contains **cell sap**. Cell sap is complex mixture of solute. It has a high concentration and tends to draw in water into the cell from the surroundings by osmosis.

When **endosmosis** occurs, water flows into the vacuole of a plant cell, causing the cell to swell. The cell, however, does not rupture because, although the cell wall stretches to a certain extent, it is tough and does not break. It also prevents the cell membrane from expanding. A high pressure builds up inside the cell and makes it **turgid**.

When **exosmosis** occurs, water flows out of the vacuole of the plant cell into the surroundings. As a result, the vacuole shrinks and eventually pulls the cytoplasm from the cell wall. This process is known as **plasmolysis**.

Haemolysis

Haemolysis is defined as the process by which red blood cells or corpuscles become split or burst as a result of too much water passing into it. This situation will occur when the red blood cell is placed in a weaker or hypotonic solution where the red blood cell takes in water and become swollen and may even burst.

Plasmolysis

Turgidity is defined as the condition in which cells absorb plenty of water up to a point where the cells is fully stretched. At this point, the cell is said to be **turgid**. Turgidity occurs when a plant is placed in a hypotonic solution (e.g. distilled water). As a result of the fact that the cytoplasm solution is stronger than the water, the cell absorbs water and becomes turgid. Turgidity is useful to land plants because it makes them stand erect and gives support to the stem, leaves, flowers and guards cells. It also makes herbaceous plants look firm.

Turgidity

Plasmolysis is defined as the outward movement or flow of water from living cells when they are placed in a hypertonic solution. Plasmolysis is often regarded as the opposite of osmosis. The process of plasmolysis involves the withdrawal of water from living cells up to the extent that it will result in the pulling away of the cytoplasm from the cell membrane or cell wall. As a result of this, the cytoplasm will shrink and the whole cell will collapse. When this happens, the cells are said to be **plasmolysed**. This will eventually lead to wilting or death of the plant.

Flaccidity

Flaccidity is defined as the condition in which plants lose water to their surroundings faster than they can absorb. When plant loses more water, it is said to be **flaccid**. Flaccidity normally occurs when there is no water in the soil or during drought. Such continuous loss of water to the surroundings may cause the plant to wilt or even die if it continues for a very long time.

Phase 4: ELABORATION

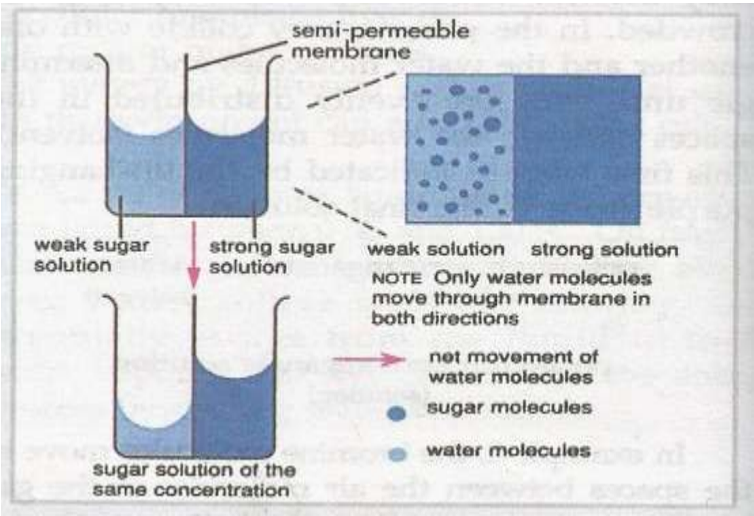
Teacher extends students' understanding of the concept by presenting further activities. i.e.:

ACTIVITY 3

Aim: To Demonstrate Osmosis through a Semi-Permeable Membrane.

Materials: Charts illustrating osmosis through a semi-permeable membrane.

Procedure: Equal volumes of very weak (dilute) sugar solution and a strong (concentrated) sugar solution are separated by a **semi-permeable membrane** as illustrated in the chart before you. **Note that a semi-permeable membrane allows only water molecules to pass through it.**



Study the chart as a group and attempt the questions that follow.

Conceptual Questions:

1. A concentration gradient exists between ________ and ____________ molecules.

2. What are the possible conclusions regarding the movement of sugar and water molecules?

3. At the end of the experiment, the strength or concentration of the sugar solution is the same on both sides of the membrane and the system is said to be in DYNAMIC EQUILIBRIUM. What does this mean in relation to the movement of sugar and water molecules?

4. From this experiment, is it right to conclude that osmosis is a special case of diffusion involving the movement of water molecules only?

Phase 5: EVALUATION

Teacher ensures that students demonstrate their achievement of the lesson objectives by asking them the following questions:

i. Define osmosis in your own words.
ii. Differentiate between a hypotonic, a hypertonic and an isotonic solution.
iii. Distinguish between endosmosis and exosmosis.
iv. Describean experiment to demonstrate the process of osmosis in non-living systems;
v. Describean experiment to demonstrate the process of osmosis in a living tissue;
vi. Briefly explain the terms osmotic pressure, osmotic potential, haemolysis, plasmolysis, turgidity and flaccidity.
vii. Draw diagrams to illustrate the effects of solutions of different strengths (or concentrations) on animal cells.
viii. Draw diagrams to illustrate the effects of solutions of different strengths (or concentrations) on plant cells.

WEEK THREE

Method of Teaching: 5Es Instructional Strategy

Subject: Biology

Group: Experimental

Class: SS II

Number of Students: 54

Topic: Active Transport, Endocytosis and Exocytosis and their Applications

Duration: 80 minutes (Double Period)

Reference Materials: Maxwell, D.A. (1998). *New Practical Biology for Senior Secondary Schools*. Ibadan: ONIBONOJE Press

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Publishers.

Michael, M.C. (2015). *Essential Biology for Senior Secondary Schools.* Ikeja: TONAD Publishers Limited.

Ramalingam, S.T. (2010). *Modern Biology for Senior Secondary Schools.* Onitsha: Africana First Publishers Plc.

Instructional Materials: Charts illustrating active transport between human red blood cells and plasma, charts showing endocytosis in a white blood cell, diagrams illustrating exocytosis in a gland cell.

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

i. define active transport correctly in their own words;
ii. describe the process of active transport between the human red blood cells and plasma;
iii. mention at least two applications of active transport in living systems;
iv. differentiate between endocytosis and exocytosis;
v. explain briefly the two types of endocytosis;
vi. mention at least one application each of endocytosis and exocytosis in living systems;
vii. distinguish between passive and active processes of transport across the plasma membrane;
viii. outline at least three importance of transport across the plasma membranes of plant and animal cells;
ix. demonstrate perseverance and objectivity as they carry out experiments; and
x. display humility and open-mindedness as they work with their peers to solve problems.

Previous Knowledge: Students are:

- familiar with the concept of diffusion and osmosis wherein molecules move from one medium to another depending on their concentration gradients;
- aware of the fact that diffusion and osmosis can occur in living and non-living systems;
- conversant with the fact that both diffusion and osmosis are passive processes and do not require energy;
- familiar with the basic differences between diffusion and osmosis.

Presentation: Teacher organizes students into 9 groups of 6 students each, highlights the topic to be learnt and emphasizes the need for each student to participate fully in classroom activities.

Phase 1: ENGAGEMENT

Teacher uses probing questions related to students' previous knowledge to capture students' attention and interest to the topic. i.e.:

i. What are the major similarities between diffusion and osmosis?
ii. What are the basic differences between diffusion and osmosis?
iii. Does diffusion apply specifically to water molecules?
iv. What are the reasons for your answer?

Phase 2: EXPLORATION

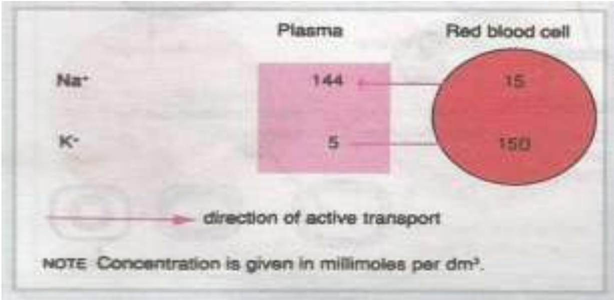
Teacher presents two activities to be carried out by students and use certain conceptual questions to encourage and focus students' exploration. i.e.:

ACTIVITY 1

Aim: To Demonstrate Active Transport in the Human Red Blood Cells and Plasma.

Materials: Charts illustrating active transport between human red blood cells and plasma.

Procedure: Placed before you is a chart illustrating active transport between human red blood cells and plasma wherein sodium ions (Na^+) and potassium ions (K^+) are exchanged between the red blood cells and the plasma as shown below:



Study the chart as a group and attempt the following questions.

Conceptual Questions:

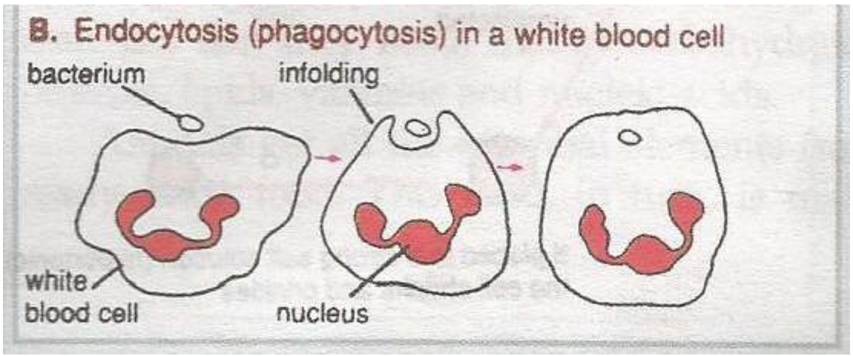
i. Where is the concentration of Na^+ more and where is it less?
ii. Does the arrow indicate that Na^+ are transported in accordance with or against their concentration gradients?
iii. Where is the concentration of K^+ more and where is it less?
iv. Does the arrow indicate that K^+ are transported in accordance with or against their concentration gradients?
v. Do you think energy is required for this process to be effective? Why?
vi. What characteristics do you think the human red blood cells posses which enable it carry out this process efficiently?

ACTIVITY 2

Aim: To Demonstrate Endocytosis (Phagocytosis) in a White Blood Cell.

Materials: Diagrams showing endocytosis in a white blood cell.

Procedure: Placed before you is a diagram illustrating how a type of white blood cell attacks a bacterium by engulfing it. This process is known as phagocytosis and it is a type of endocytosis.



Study the diagram as a group and answer the questions that follow.

Conceptual Questions:

i. What happens to the plasma membrane that surrounds the bacterium?
ii. Do you think energy is necessary for this process? Why?
iii. If the bacterium is eventually digested and waste particles are to be removed, what do you call that process of waste removal?
iv. Would energy be required for that process too? Why?

Phase 3: EXPLANATION

Teacher solicits students' explanations regarding certain keywords and phenomena as it relates to their exploration and helps them justify their explanations. i.e.:

i. What do you understand by the terms 'active transport', 'endocytosis' exocytosis' and 'passive transport'?
ii. What applications does each term above have in living systems?
iii. Differentiate between the two types of endocytosis.

Teacher also provides explanations of concepts and phenomena related to the topic in a direct and formal manner. i.e.:

Meaning of Active Transport

Active transport is defined as the movement of solute molecules and ions across a membrane from a region of low concentration to a region of high concentration with resultant energy consumption.

Active Transport between Human Red Blood Cells and Plasma

Sodium ions are in low concentration in a human red blood cell and in high concentration in the plasma. Yet, sodium ions are transported out of the cell into the plasma, against the existing concentration gradient. In a similar manner, potassium ions are transported from the plasma into the cell. This process is known as active transport and always requires energy. It often occurs against a concentration gradient as in the above example.

Applications of Active Transport in Living Systems

Active transport is particularly important in:

i. cells lining the gut, where absorption of digested food substances occurs; and
ii. cells of the kidney tubules, where reabsorption occurs.

Cells carrying out active transport have:

- numerous mitochondria;
- a high concentration of ATP (immediate energy store); and
- a high cellular respiratory rate.

Endocytosis and Exocytosis

Endocytosis: Endocytosis is defined the process by which the plasma membrane of a cell folds inwards to ingest or take up material into the cell in a vesicle or vacuole with resultant energy consumption.

Exocytosis: Exocytosis is defined as the process by which materials are transported out of a cell by means of vesicles or an extension of the plasma membrane with resultant energy consumption.

Types of Endocytosis

Both **Phagocytosis** and **Pinocytosis** are endocytotic processes.

i. The tern **'Phagocytosis'** is used when solid materials are taken into the cell by engulfing them.
ii. The term **'Pinocytosis'** is used when liquid materials are taken into the cell.

Applications of Endocytosis and Exocytosis in Living Systems

- An*Amoeba* captures its food and a white blood cell engulfs bacteria that invade the body by Phagocytosis (Endocytosis).
- Hormones and enzymes are secreted from the cells in which they are made by reverse Pinocytosis (Exocytosis).

Passive and Active Processes of Transport across the Plasma Membrane

There are four methods of entry into or exit from cells. These are **diffusion**, **osmosis**, **active transport** and **Endocytosis** or **Exocytosis**.

- **Diffusion and Osmosis** are passive processes and do not require energy. They only depend on a concentration gradient.
- **Active Transport and Endocytosis or Exocytosis** are active processes and do require energy. They do not depend on a concentration gradient.

Importance of Transport across the Plasma Membranes of Plant and Animal Cells

Transport across the plasma membranes of plant and animal cells is important to cells for:

i. obtaining oxygen and nutrients (to supply energy and raw materials for syntheses);
ii. excreting toxic substances (result of metabolic activities); and
iii. maintaining a suitable pH and solute concentration (for enzyme activity).

Phase 4: ELABORATION

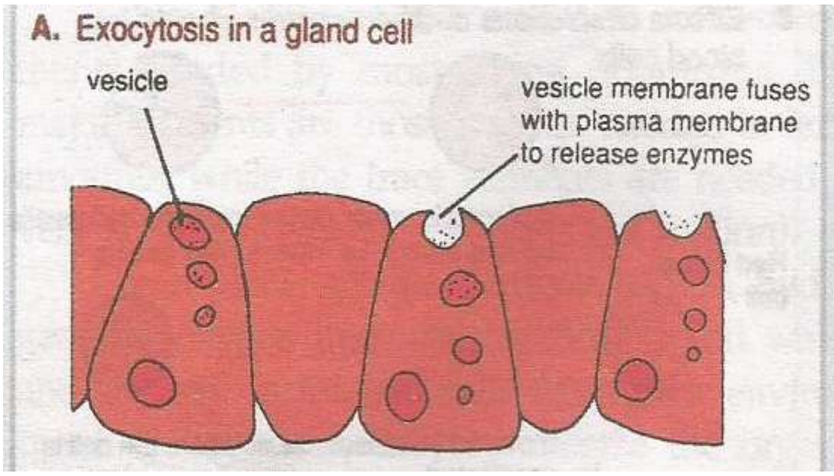
Teacher extends students' understanding of the concept by presenting further activities. i.e.:

ACTIVITY 3

Aim: To Demonstrate Exocytosis in a Gland Cell.

Materials: Charts illustrating exocytosis in a gland cell.

Procedure: Placed before you is a chart illustrating how a gland cell secretes hormones or enzymes. This process is known as exocytosis or reverse pinocytosis.



Study the diagram as a group and answer the questions that follow.

Conceptual Questions:

i. What happens to the vesicles when they reach the plasma membrane?
ii. Do you think energy is necessary for this process? Why?
iii. If the cell were to take in liquid materials, what name would best refer to that process?
iv. Would energy be required for that process too? Why?

Phase 5: EVALUATION

Teacher ensures that students demonstrate their achievement of the lesson objectives by asking them the following questions:

i. Define active transport in your own words.
ii. Describe the process of active transport between the human red blood cells and plasma.
iii. Mention two applications of active transport in living systems.
iv. Differentiate between endocytosis and exocytosis.
v. Briefly explain the two types of endocytosis.
vi. Mention one application each of endocytosis and exocytosis in living systems.
vii. Distinguish between passive and active processes of transport across the plasma membrane.
viii. Outline three importance of transport across the plasma membranes of plant and animal cells.

WEEK FOUR

Method of Teaching: 5Es Instructional Strategy

Subject: Biology

Group: Experimental

Class: SS II

Number of Students: 54

Topic: Catabolic Processes: Cellular Respiration

Duration: 80 minutes (Double Period)

Reference Materials: Maxwell, D.A. (1998). *New Practical Biology for Senior Secondary Schools*. Ibadan: ONIBONOJE Press -

Publishers.

Michael, M.C. (2015). *Essential Biology for Senior Secondary Schools.* Ikeja: TONAD Publishers Limited.

Ramalingam, S.T. (2010). *Modern Biology for Senior Secondary Schools.* Onitsha: Africana First Publishers Plc.

Instructional Materials: Sugar, hard glass tube, delivery tube, copper(II) sulphate, lime water, charts illustrating an experimental set-up to show that a mouse respires aerobically, charts illustrating an experimental set-up to show that in the absence of oxygen, yeast respires anaerobically, charts illustrating an experimental set-up to show that heat is produced during cellular respiration.

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

i. define catabolism and cellular respiration in their own words;
ii. explain with the aid of chemical equations the two types of cellular respiration;
iii. explain briefly how energy is released from food in a living cell;
iv. perform an experiment to show that carbon dioxide and water vapour are given off when food is burnt;
v. mention at least three differences between aerobic and anaerobic respiration;
vi. outline at least three similarities between aerobic and anaerobic respiration;
vii. perform one experiment each to demonstrate aerobic and anaerobic respiration in named organisms;
viii. perform an experiment to show that heat energy is given out during cellular respiration;
ix. demonstrate perseverance and objectivity as they carry out experiments; and
x. display humility and open-mindedness as they work with their peers to solve problems.

Previous Knowledge: Students are:

- familiar with the concept of respiration as the exchange of gases (oxygen and carbon dioxide) between organisms and their environment;
- aware of the fact that respiration is a fundamental characteristic of all living things;
- conversant with the fact that the purpose of respiration is to oxidize food substances in order to release energy which is used for all life processes.

Presentation: Teacher organizes students into 9 groups of 6 students each, then highlights the topic to be learnt and emphasizes the need for each student to participate fully in classroom activities.

Phase 1: ENGAGEMENT

Teacher uses probing questions related to students' previous knowledge to capture students' attention and interest to the topic. i.e.:

i. What is respiration?
ii. What are the gases we humans breathe in and breathe out?
iii. It is often said that plants take in carbon dioxide and give out oxygen during respiration. Is that scientifically correct? Why?
iv. Why do living organisms respire?
v. Differentiate between breathing and respiration.
vi. Differentiate between respiration and combustion.

Phase 2: EXPLORATION

Teacher presents three activities to be carried out by students and use certain conceptual questions to encourage and focus students' exploration. i.e.:

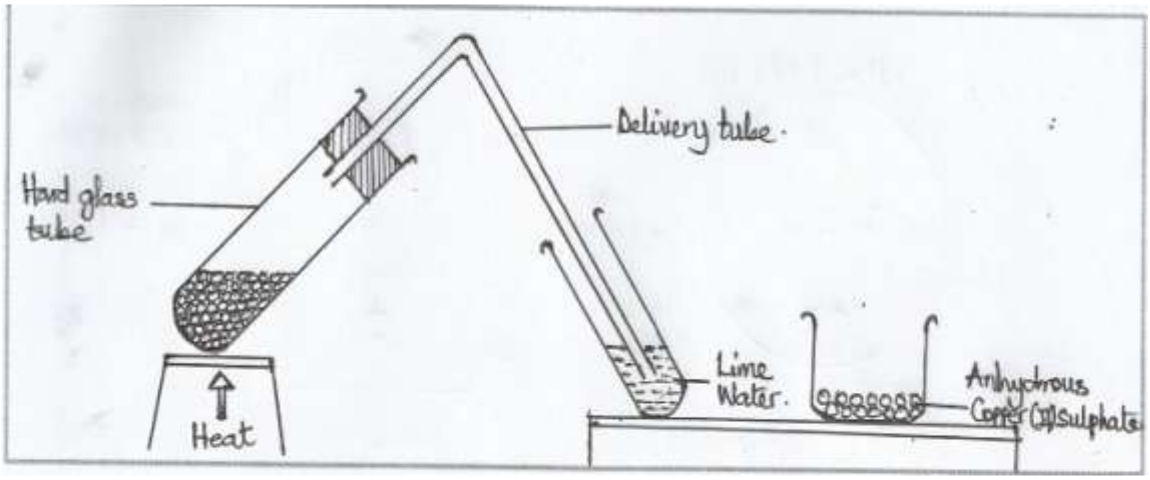
ACTIVITY 1

Aim: To Show that Carbon dioxide and Water Vapour are Given Off when Food is Burnt.

Materials: Sugar, hard glass tube, delivery tube, copper (II) sulphate, lime water.

Procedure: Set up the apparatus as illustrated in the chart below. Heat the sugar in the hard glass tube and pass the products formed through:

i. White anhydrous copper (II) sulphate crystals; and
ii. Lime water.



Make careful observations and attempt the questions that follow as a group.

Conceptual Questions:

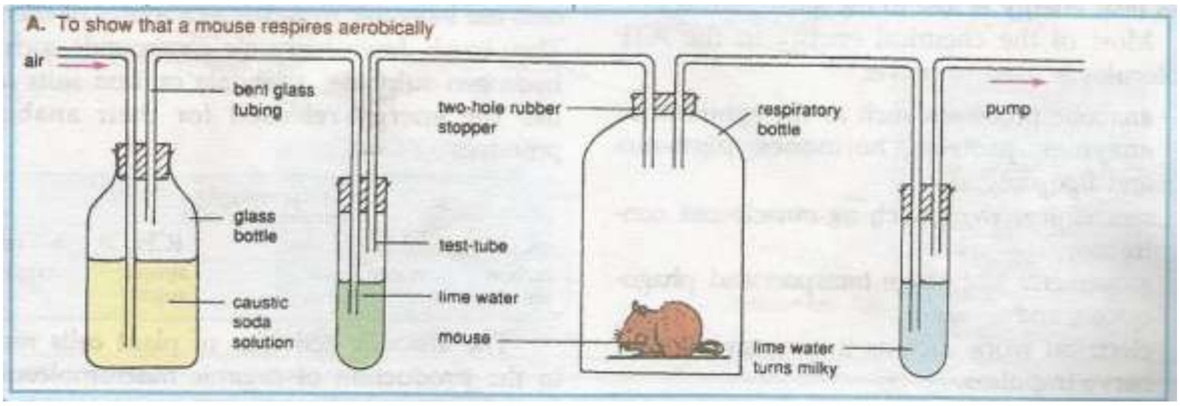
i. What did you observe when the fumes from the heated sugar came in contact with the white anhydrous copper (II) sulphate crystals?
ii. What can you infer from that observation?
iii. What did you observe when the fumes from the heated sugar came in contact with the lime water?
iv. What can you infer from that observation?
v. Does sugar therefore qualify as a food substance?

ACTIVITY 2

Aim: To Show that a Mouse Respires Aerobically.

Materials: Charts illustrating an experimental set-up to show that a mouse respires aerobically.

Procedure: Placed before you is a chart illustrating an experimental set-up to show that a mouse respires aerobically.



Study the chart carefully as a group and answer the questions that follow.

Conceptual Questions:

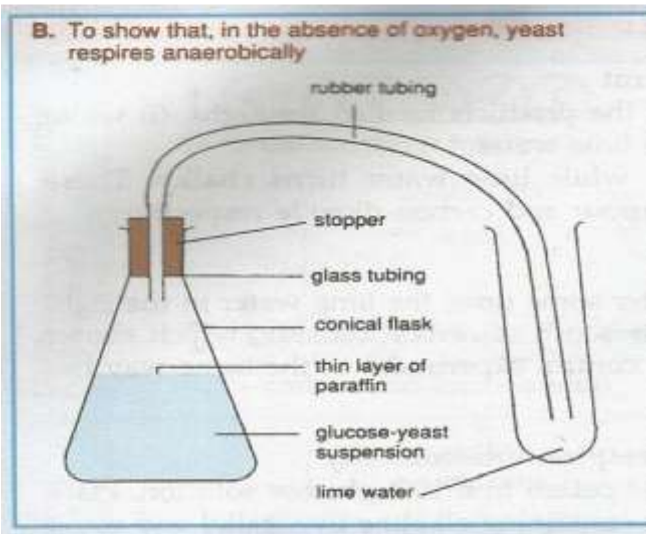
i. What change(s) is/are likely to be noticed after 5minutes of starting the experiment?
ii. Why do you think that change or those changes will occur?
iii. What function does caustic soda solution perform in the experiment?
iv. What function does lime water A perform in the experiment?
v. What function does lime water B perform in the experiment?
vi. Do you think the mouse could die after two hours? Why?

ACTIVITY 3

Aim: To Show that in the Absence of Oxygen, Yeast Respires Anaerobically.

Materials: Charts illustrating an experimental set-up to show that in the absence of oxygen, yeast respires anaerobically.

Procedure: Placed before you is a chart illustrating an experimental set-up to show that in the absence of oxygen, yeast respires anaerobically.



Study the chart carefully as a group and answer the questions that follow.

Conceptual Questions:

i. Boiled and cooled water is used to make the glucose-yeast suspension. Why?
ii. Why do you think the glucose-yeast suspension is covered in a thin layer of paraffin oil?
iii. After 2 hours of starting the experiment, bubbles of a gas will be seen in the glucose yeast suspension. What gas is likely to be contained in these bubbles?
iv. What change is likely to be noticed in the lime water?
v. If a burning splinter is inserted into the conical flask, what is likely to happen to the flame?
vi. Why do you think this gas will be produced?
vii. What is likely to be produced in the conical flask at the end of the experiment?
viii. What alternative method can be used to exclude oxygen from the system?

Phase 3: EXPLANATION

Teacher solicits students' explanations regarding certain keywords and phenomena as it relates to their exploration and helps them justify their explanations. i.e.:

i. What do you understand by the terms 'catabolism' and 'cellular respiration'?
ii. Differentiate between the two types of cellular respiration.
iii. Compare and contrast the terms 'aerobic' and 'anaerobic' respiration.

Teacher also provides explanations of concepts and phenomena related to the topic in a direct and formal manner. i.e.:

Meaning of Catabolism

Catabolism is defined as the breaking down of complex organic molecules into simple substances coupled with the release of energy. Examples of catabolic processes in the body are respiration, fermentation and digestion.

Meaning of Cellular Respiration

Cellular respiration involves the chemical activities of the cells in which glucose is broken down by a series of reactions controlled by enzymes to release energy. The energy released is stored in adenosine triphosphate (ATP). ATP is the form in which energy is carried, stored and used by all living cells for the various metabolic processes. The entire purpose of cellular respiration is to generate energy for various metabolic processes in all organisms.

Types of Cellular Respiration

There are two main types of cellular Respiration. These are **aerobic** and **anaerobic** respiration

Aerobic Respiration: Aerobic Respiration is the type of respiration which requires oxygen to break down glucose (substrates) into water, carbon dioxide and energy (ATP). Aerobic respiration can be represented by the chemical equation below:

$C_6H_{12}O_6$ + $6O_2$ → $6CO_2$ + $6H_2O$ + Energy
(Glucose) (Oxygen) (Carbon dioxide) (water) (ATP)

Anaerobic Respiration: Anaerobic Respiration is the type of which does not require the presence of oxygen to provide energy. During anaerobic respiration, glucose is broken down to yield carbon dioxide, alcohol(ethanol) and energy. The anaerobic respiration can be represented by a chemical equation as:

$C_6H_{12}O_6$ → $2C_2H_5OH$ + $2CO_2$ + Energy
(Glucose) (Alcohol) (Carbon dioxide) (ATP)

Release of Energy from Food

When food is burnt in the laboratory, the following reaction occurs:

Food + Oxygen → Carbon dioxide + Water + Energy

Oxygen is necessary for food to burn. It is, therefore, an oxidation reaction. The complex food substance is broken down to liberate the simple molecules, carbon dioxide and water, and energy. The reaction is rapid and heat is given off in large amounts in one big step.

Scientists have shown that food is also burnt in a similar way in living cells. The main food that is burnt in cells is glucose. This oxidation process which produces energy, carbon dioxide and water is summarized below:

$C_6H_{12}O_6$ + $6O_2$ → $6CO_2$ + $6H_2O$ + Energy
(Glucose) (Oxygen) (Enzymes) (Carbon dioxide) (Water) (ATP)

However, the energy is not released in one big step as shown in the above reaction, but in a series of small steps which are catalysed by enzymes. The energy that is released, bit by bit, is stored in adenosine triphosphate (ATP) molecules. The oxidation of glucose to release energy in this manner is known as cellular respiration. It occurs in the mitochondria of all living cells.

During Cellular respiration, one molecule of the **6-Carbon glucose** is broken down into two molecules of the **3-carbon Pyruvic acid** by enzymes in the cytoplasm of the cell. These reactions do not require oxygen. Each molecule of Pyruvic acid is oxidized completely to carbon dioxide and water in the mitochondrion. This latter series of reactions is known as the Kreb's Cycle. Most of the ATP molecules is formed in this cycle. A total of 38 ATP molecules are formed when one molecule of glucose is completely oxidized.

When needed, lipids and proteins are broken down to small molecules and enter the Kreb's cycle at various points.

Differences between Aerobic and Anaerobic Respiration

Aerobic Respiration	Anaerobic Respiration
(a) Oxygen is required for oxidation.	Oxygen is not required for oxidation.
(b) By-products are water and carbon dioxide.	By-products are alcohol or lactic acid.
(c) More energy is released.	Less energy is released.
(d) It takes place in mitochondria.	It takes place in cytoplasm.
(e) Water is given off as by-product.	Alcohol is given as by-product.

Similarities between Aerobic and Anaerobic Respiration

(a) Both aerobic and anaerobic respiration lead to the release of energy.
(b) Both occur in plant and animal cells.
(c) Both processes require enzymes to speed up the reactions.
(d) Both processes lead to the generation of heat.
(e) Both give off carbon dioxide as by product.

Phase 4: ELABORATION

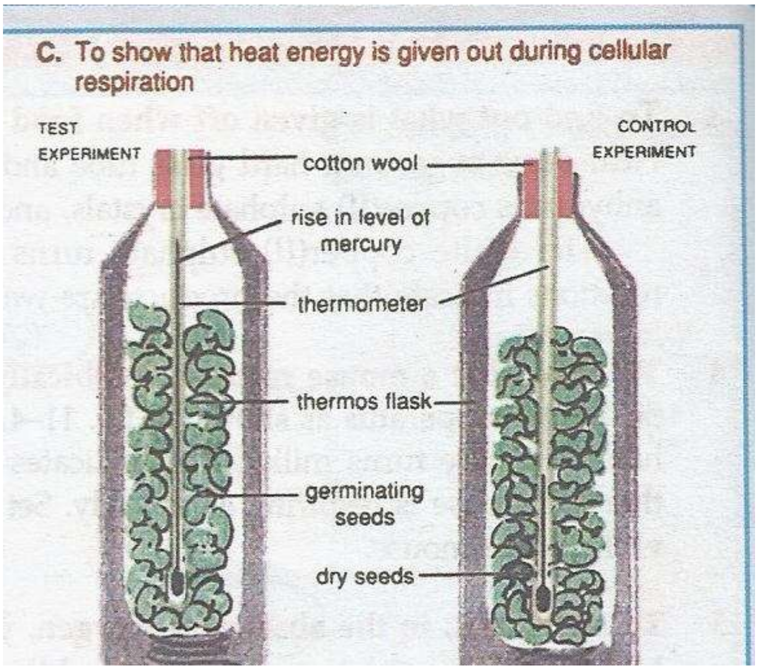
Teacher extends students' understanding of the concept by presenting further activities. i.e.:

ACTIVITY 3

Aim: To show that heat energy is given out during cellular respiration.

Materials: Charts illustrating an experimental set-up to show that heat is produced during cellular respiration.

Procedure: Placed before you is a chart illustrating an experimental set-up to show that heat is produced during cellular respiration. A few drops of 5% formalin was sprinkled over the seeds in the two flasks to prevent fungal or bacterial growth.



Study the chart as a group and answer the questions that follow.

Conceptual Questions:

i. Why do you think fungal and bacterial growth has to be prevented in both flasks?
ii. What observation(s) is/are likely to be made after 3 hours of starting the experiment?
iii. What are the reasons for these likely observations?
iv. Why do you think thermos flasks are used for the experiment?
v. The bulb of the thermometer should be well buried in the seeds. Why?

Phase 5: EVALUATION

Teacher ensures that students demonstrate their achievement of the lesson
objectives by asking them the following questions:

i. Define catabolism and cellular respiration in your own words.
ii. With the aid of chemical equations, explain the two types of cellular respiration.
iii. Briefly explain how energy is released from food in a living cell.
iv. Describe an experiment to show that carbon dioxide and water vapour are given off when food is burnt.

v. Mention three differences between aerobic and anaerobic respiration.

vi. Outline three similarities between aerobic and anaerobic respiration.

vii. Describe an experiment each to demonstrate aerobic and anaerobic respiration in named organisms.

viii. Describe an experiment to show that heat energy is given out during cellular respiration.

WEEK FIVE

Method of Teaching: 5Es Instructional Strategy

Subject: Biology

Group: Experimental

Class: SS II

Number of Students: 54

Topic: Anabolic Processes: Photosynthesis

Duration: 80 minutes (Double Period)

Reference Materials: Maxwell, D.A. (1998). *New Practical Biology for Senior Secondary Schools*. Ibadan: ONIBONOJE Press

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Publishers.

Michael, M.C. (2015). *Essential Biology for Senior Secondary Schools.* Ikeja: TONAD Publishers Limited.

Ramalingam, S.T. (2010). *Modern Biology for Senior Secondary Schools.* Onitsha: Africana First Publishers Plc.

Instructional Materials: Boiling Water, Leaves from a plant exposed to sunlight, Variegated Leaf (a leaf from *Coleus*, *Croton* or *Acalypha* Plant), Hot Alcohol, Test Tube, Iodine Solution and White Tile Charts illustrating Adaptation of Leaf Structure for Photosynthesis, Real Leaves from Dicotyledonous and Monocotyledonous Plants.

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

i. define anabolism in their own words;
ii. outline at least three examples of anabolic processes;
iii. explain briefly the main features of photosynthesis in four steps;
iv. explain the chemistry of photosynthesis with the aid of simple chemical equations;
v. perform an experiment to show that starch is produced during photosynthesis;
vi. draw the section of a leaf to show its adaptations for photosynthesis;
vii. perform an experiment to show that chlorophyll is necessary for photosynthesis
viii. explain briefly the fate of photosynthetic products;
ix. mention at least three importance of photosynthesis to life;
x. demonstrate perseverance and objectivity as they carry out experiments; and
xi. display humility and open-mindedness as they work with their peers to solve problems.

Previous Knowledge: Students are:

- aware of the fact that most plants are green and all green plants can manufacture their own food via photosynthesis;
- conversant with the fact that all animals cannot manufacture their own food but have to feed on plant materials to survive, grow and reproduce.

Presentation: Teacher organizes students into 9 groups of 6 students each. Then, highlights the topic to be learnt and emphasizes the need for each student to participate fully in classroom activities.

Phase 1: ENGAGEMENT

Teacher uses probing questions related to students' previous knowledge to capture students' attention and interest to the topic. i.e.:

i. Why are most plants in our environment green?
ii. How do plants make their food?
iii. Why do plants need sunlight to make their food?
iv. In what ways do you think organic molecules manufactured by plants are utilized by them?
v. Why do you think animals need to feed on plants or plant materials?
vi. In what ways do you think animals utilize the organic molecules they derive from plants?

Phase 2: EXPLORATION

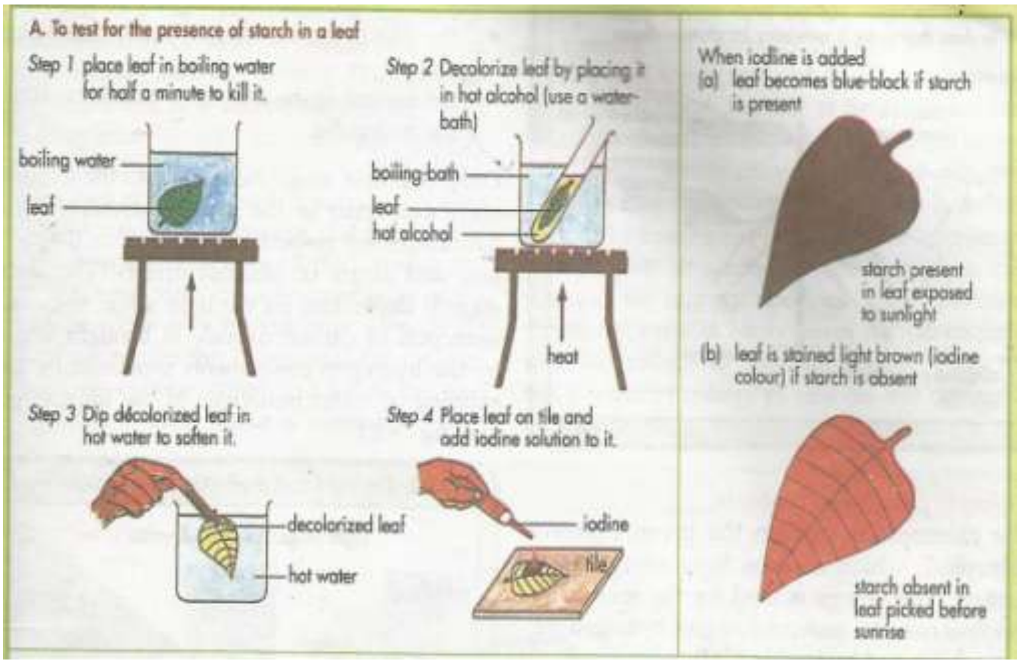
Teacher presents three activities to be carried out by students and use certain conceptual questions to encourage and focus students' exploration. i.e.:

ACTIVITY 1

Aim: To Show that Starch is Produced in a Leaf during Photosynthesis.

Materials: Boiling Water, Leaf from Plant Exposed to Sunlight, Hot Alcohol, Test Tube, Iodine Solution, White Tile.

Procedure: Pluck a leaf from a plant exposed to sunlight for a few hours. Place the leaf in boiling water for 30 seconds. Place leaf in hot alcohol (heated in a water bath) for 1 minute. Dip decolorized leaf in hot water to soften it. Place leaf on white tile and add 2 drops of iodine solution to it. Pay close attention to the change in colour of the leaf.



Make careful observations and attempt the questions that follow as a group.

Conceptual Questions:

i. What did you observe when the leaf was placed in boiling water after 30 seconds?
ii. What can you infer from that observation?
iii. What did you observe when the leaf was placed in hot alcohol after 1 minute?
iv. What can you infer from that observation?
v. What did you observe when iodine solution was added to the leaf?
vi. What can you infer from that observation?
vii. What do you think would happen if the leaf was plucked before sunrise and tested for starch?

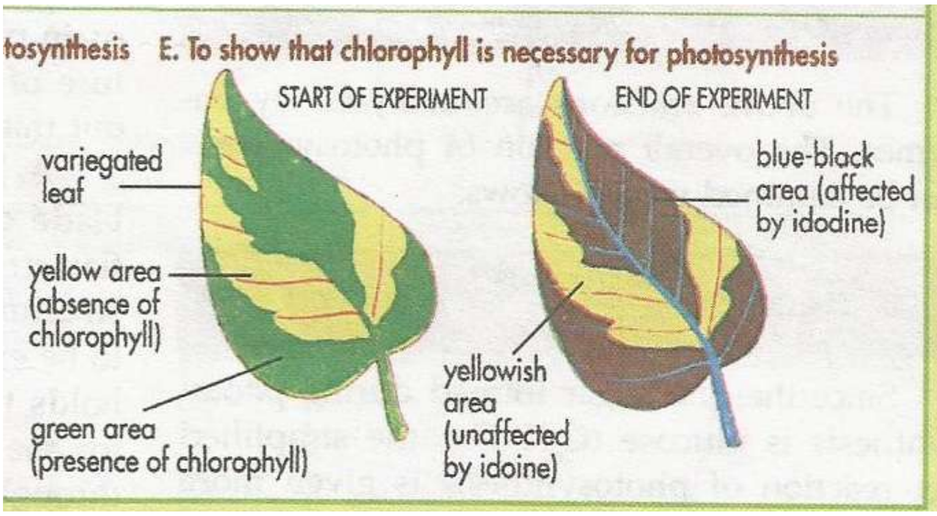
ACTIVITY 2

Aim: To Show that Chlorophyll is Necessary for Photosynthesis.

Materials: Boiling Water, Variegated Leaf (a leaf from *Coleus*, *Croton* or *Acalypha* Plant), Hot Alcohol, Test Tube, Iodine Solution and White Tile.

Procedure: Take a variegated leaf that has been exposed to sunlight for a few hours.
Draw a diagram to show the distribution of the green colour of the

leaf. Then test the leaf for starch. Pay close attention to the change in colour of the green and non-green parts of the leaf.



Make careful observations and attempt the questions that follow as a group.

Conceptual Questions:

i. What did you notice on the green parts of the leaf when iodine solution was added?
ii. What can you infer from that observation?
iii. What did you notice on the non-green parts of the leaf when iodine solution was added?
iv. What can you infer from that observation?

Phase 3: EXPLANATION

Teacher solicits students' explanations regarding certain keywords and phenomena as it relates to their exploration and helps them justify their explanations. i.e.:

i. What do you understand by the terms 'anabolism' and 'photosynthesis' ?
ii. What do you think are the factors necessary for photosynthesis?
iii. What do you think are the importance of photosynthesis to life?

Teacher also provides explanations of concepts and phenomena related to the topic in a direct and formal manner. i.e.:

Meaning of Anabolism

Anabolism is defined as the building up of complex organic molecules from simple ones in a biological system. In anabolic process, energy is usually consumed because some forms of energy are required first to break the old molecules before building up the complex ones.

Examples of Anabolic Processes

Common examples of anabolic processes are:

(a) The formation of glycogen from glucose.
(b) The formation of starch from glucose.
(c) The formation of proteins from amino acids.
(d) The formation of fats and oils from fatty acids and glycerol.
(e) Photosynthesis in green plants.

Main Features of Photosynthesis

Photosynthesis is the process by which green plants manufacture food. Photosynthesis is important not only to plants themselves but also to animals, which depend on plants for food. The main features of photosynthesis are as follows:

- Photosynthesis takes place in the chloroplasts of plant cells, in the presence of sunlight.
- The raw materials of the process are the low-energy containing inorganic compounds, carbon dioxide and water.
- The final products of the process are high-energy containing sugars (organic compounds). Oxygen is given off as a waste product.
- The energy needed to drive this anabolic process comes from the sunlight absorbed by chlorophyll, the green pigment found in chloroplasts.

The gases, carbon dioxide and oxygen, move in and out between the surrounding air and leaves through stomatal openings on the leaf surfaces. Water from the soil enters the root hairs, by osmosis. From the root hairs, it is conducted upwards through the stem to the leaves.

Most of the sugars produced are changed into starch in the leaf cells. They are stored in this insoluble form until night-time. Then, the starch is converted back into sugars (soluble form) to be transported to other parts of the plant where they are needed. This movement of sugars is known as **translocation**.

In the cells, the sugars are used as a source of energy. Some plants have special storage organs where the sugar is converted back to starch to be stored for long periods of time. The storage organs may be roots, stems, fruits or seeds.

Chemistry of Photosynthesis

The chloroplasts contain the green pigment **chlorophyll**, which absorbs light energy from sunlight. This energy is used for the splitting or **photolysis** of water molecules to give **hydrogen (H)** components and **hydroxide (OH)** components.

(1) $4H_2O \rightarrow 4H + 4OH$

The **OH** components undergo further reactions to produce water and oxygen.

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

The **H** components undergo a series of reactions in which they reduce carbon dioxide to form sugar.

(3) $CO_2 + 4H \rightarrow CH_2O + H_2O$

The above reactions are catalysed by enzymes. The overall reaction of photosynthesis can be summed up as follows:

(4) $2H_2O + CO_2 \xrightarrow[\text{chlorophyll}]{\text{energy, enzymes}} CH_2O + H_2O + O_2$

Since the first sugar formed during photosynthesis is glucose ($C_6H_{12}O_6$), the simplified net reaction of photosynthesis is given more specifically as follows:

$$6H_2O + 6CO \xrightarrow[\text{chlorophyll}]{\text{energy, enzymes}} C_6H_{12}O_6 + 6O_2$$

NOTE: During photosynthesis, the oxygen liberated comes **only** from water molecules, not from carbon dioxide.

From the above, we see that photosynthesis consists of two essential stages:

- the first is the splitting of water molecules; and
- the second is the reduction of carbon dioxide molecules.

Only the first stage needs light; the second stage can occur in the dark. Therefore, these two stages are respectively are known as **light** and **darkstages** of photosynthesis. The dark stage is dependent on the light stage, since the reduction of carbon dioxide is brought about by the hydrogen components produced by the splitting of water molecules in the light stage.

Structural Adaptations of the Leaf to Photosynthesis

Leaf as a Photosynthetic Organ

Although all the parts of the plant can carry out photosynthesis, the leaves are the main photosynthetic organs. As such, the structure of a leaf is specially adapted for carrying out this function.

Structure	Adaptation
Leaf Stalk	Able to hold leaf blade in the best position to receive maximum amount of sunlight.
Leaf Blade	Large surface area for receiving sunlight; thin structure to ensure that the carbon dioxide that enters the leaf can rapidly reach each leaf cell by diffusion.
Stomata	Present on leaf surface in large numbers to allow entry and exit of gases and water vapour from leaf.
Intercellular Spaces	Present throughout leaf, linking the interior of leaf to the external environment, enabling diffusion and distribution of gases and water vapour from and to all photosynthetic cells.
Transport Tissue	Well distributed throughout leaf to bring water to each photosynthetic cell and remove manufactured food from it.
Mesophyll Tissue	Cells especially at the upper surface, contain numerous chloroplasts to carry out photosynthesis.

Fate of Photosynthetic products

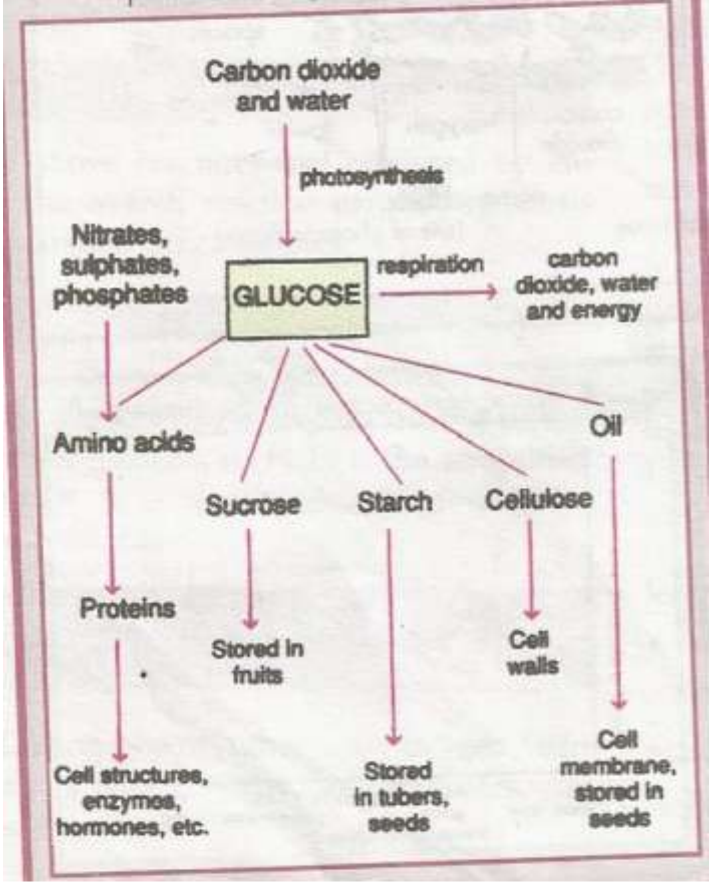
The energy-rich products of photosynthesis(food) are used by plants

- as a source of energy for their activities; and
- for producing most of the materials needed by them for growth and reproduction.

For example, glucose, an important photosynthetic product, is broken down in plants cells to provide energy. The cells also use glucose to build up many organic that the plant needs. Excess glucose is converted to substances, such as sucrose, starch and oils, which are then stored in various parts of the plant.

When a plant is eaten by an animal, the digestible food substances in the plant are broken down to their basic units and absorbed into the animal’s body. In the cells of the animal, these substances are used for proving energy and for building-up the many organic compounds that the animal needs. Excess food materials may be broken down and excreted or converted to storage substances such as fats and glycogen.

Fig. 3-5 Glucose manufactured during photosynthesis provides most of the needs of plants



Importance of Photosynthesis to Life

Photosynthesis is very important in food cycles as it is the only process that can tap the sun's enormous energy supply. Animals and other heterotrophs cannot make use of the sun's energy and simple substances to manufacture energy-rich food. Therefore, all heterotrophs are directly or indirectly dependent on green plants for food.

Photosynthesis also helps to purify the environment by removing carbon dioxide from the environment and adding oxygen to it. If not, the atmosphere will become saturated with carbon dioxide released during respiration, decomposition and combustion.

Phase 4: ELABORATION

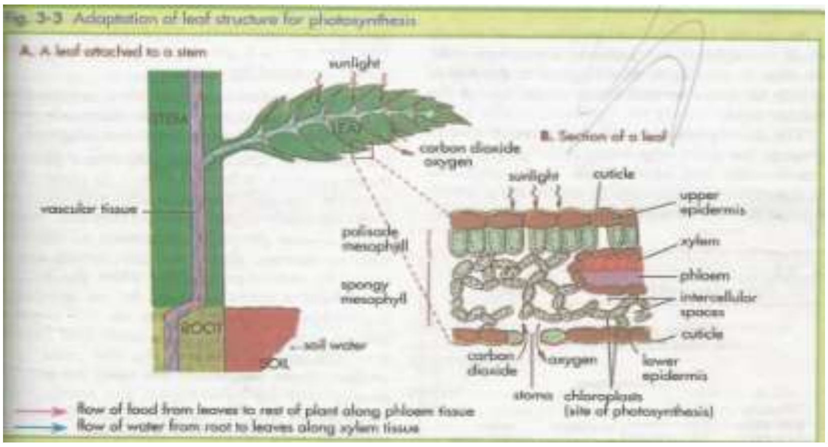
Teacher extends students' understanding of the concept by presenting further activities. i.e.:

ACTIVITY 3

Aim: To show the Structural Adaptations of a Leaf to Photosynthesis.

Materials: Charts illustrating Adaptation of leaf Structure for Photosynthesis, Real Leaves from Dicotyledonous and Monocotyledonous Plants

Procedure: Placed before you are dicot and monocot leaves as well as a chart illustrating adaptation of leaf structure for photosynthesis.



Study the specimens and chart as a group and answer the questions that follow.

Conceptual Questions:

i. Mention any two structural differences between the monocot and dicot leaves.
ii. Why do you think the lamina or leaf blades in both leaves are thin and flat?
iii. What functions do the midrib and veins serve?
iv. What functions do the cuticle and epidermis serve?
v. What functions do the stomata and guard cells serve?
vi. What functions do the mesophyll cells perform?
vii. Why do you think the intercellular spaces are linked to the stomatal openings?

Phase 5: EVALUATION

Teacher ensures that students demonstrate their achievement of the lesson objectives by asking them the following questions:

i. Define anabolism in your own words.
ii. Outline three examples of anabolic processes.

iii. Briefly explain the main features of photosynthesis in four steps.
iv. With simple chemical equations, explain the chemistry of photosynthesis.
v. Describe an experiment to show that starch is produced during photosynthesis.
vi. Describe an experiment to show that chlorophyll is necessary for photosynthesis.
vii. With a diagram, describe the structural adaptations of a leaf to photosynthesis.
viii. Briefly explain the fate of photosynthetic products.
ix. Mention three importance of photosynthesis to life.

WEEK SIX

Method of Teaching: 5Es Instructional Strategy

Subject: Biology

Group: Experimental

Class: SS II

Number of Students: 54

Topic: Mitosis and Meiosis and their Applications

Duration: 80 minutes (Double Period)

Reference Materials: Maxwell, D.A. (1998). *New Practical Biology for Senior Secondary Schools*. Ibadan: ONIBONOJE Press Publishers.

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Michael, M.C. (2015). *Essential Biology for Senior Secondary Schools.* Ikeja: TONAD Publishers Limited.

Ramalingam, S.T. (2010). *Modern Biology for Senior Secondary Schools.* Onitsha: Africana First Publishers Plc.

Instructional Materials: Charts Showing the Different Stages of Mitosis, Charts Showing the Different Stages of Meiosis, Charts illustrating

Chromosome Number in Gamete Production and Fertilization in Humans.

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

i. define mitosis and meiosis in their own words;
ii. match correctly the stages of mitosis with their diagrams based on given descriptions;
iii. mention at least three importance of mitosis;
iv. outline at least two life examples of mitotic processes in plants and animals;
v. match correctly the stages of meiosis with their diagrams based on given descriptions;
vi. mention at least three importance of meiosis;
vii. outline at least two life examples of meiotic processes in plants and animals;
viii. mention at least five differences between mitosis and meiosis;
ix. demonstrate perseverance and objectivity as they carry out experiments; and
x. display humility and open-mindedness as they work with their peers to solve problems.

Previous Knowledge: Students are:

- aware that all living organisms are made up of cells and that they grow by the multiplication of and enlargement of their cells;
- conversant with the fact that all unicellular organisms reproduce by different forms of cell division.

Presentation: Teacher organizes students into 9 groups of 6 students each, then highlights the topic to be learnt and emphasizes the need for each student to participate fully in classroom activities.

Phase 1: ENGAGEMENT

Teacher uses probing questions related to students' previous knowledge to capture students' attention and interest to the topic. i.e.:

i. How is it possible for a cell to multiply itself?
ii. In how many different ways can a cell divide?
iii. There are different types of cells in the bodies of plants and animals. Do you think all these specialized cells have the ability to multiply?
iv. What are the different forms of cell division found in unicellular organisms such as bacteria, amoeba, paramecium, euglena and yeast?
v. How do living things grow? Do you think their cells just multiply or just enlarge?

Phase 2: EXPLORATION

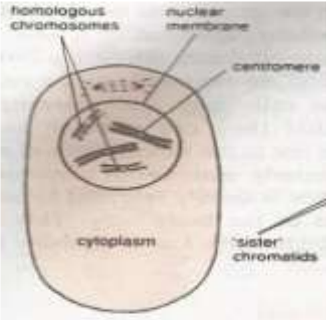
Teacher presents three activities to be carried out by students and use certain conceptual questions to encourage and focus students' exploration. i.e.:

ACTIVITY 1

Aim: To Match the Stages of Mitosis with their Appropriate Diagrams.

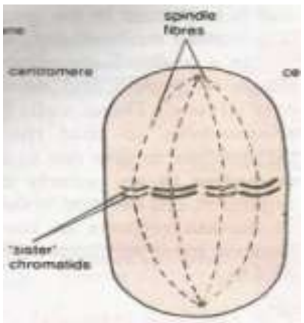
Materials: Charts Showing the Different Stages of Mitosis.

Procedure: Presented to you is a chart showing the stages (or phases) of mitosis. Brief descriptions of each phase are also provided as a guide.



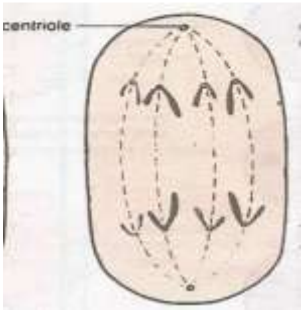
begin to

The sister chromatids are pulled apart to opposite ends (poles) of the cell as the spindle fibres contract.



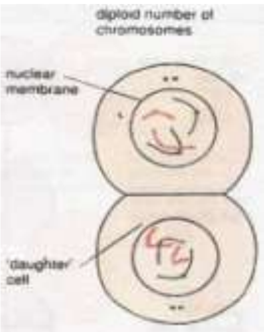
PROPHASE

Each chromosome shortens and thickens, and is seen to consist of two chromatids; the centrioles



TELOPHASE

A nuclear membrane forms around each set of chromatids, and the cell divides into two daughter cells.



METAPHASE

The nuclear membrane disappears; a spindle forms; the chromosomes line up across the middle of the cell and become attached to the spindle fibres at their centromeres.

Read the descriptions carefully and study the chart as a group. Then answer the questions that follow.

Conceptual Questions:

i. Match each phase of mitosis to the most appropriate diagram that describes it.
ii. What do you think could happen if each chromosome fails to duplicate at Prophase?

iii. What do you think could happen if each sister chromatid fails to separate at Anaphase?

iv. What do you think could happen if the cell fails to divide at Telophase?

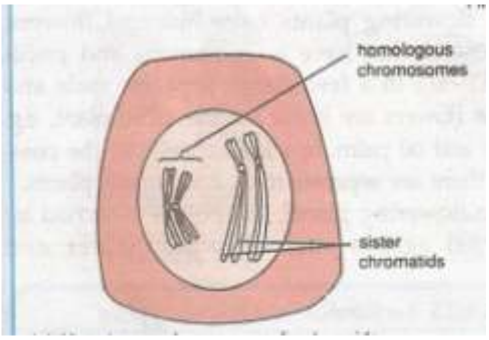
ACTIVITY 2

Aim: To Match the Stages of Meiosis with their Appropriate Diagrams.

Materials: Charts Showing the Different Stages of Meiosis.

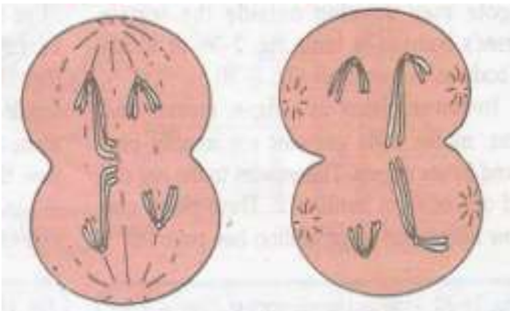
Procedure: Presented to you is a chart showing the stages (or phases) of meiosis.

Brief descriptions of each phase are also provided as a guide.



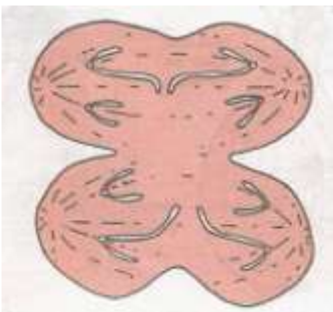
ANAPHASEI / TELOPHASEI

Chromosomes separate during first nuclear division.



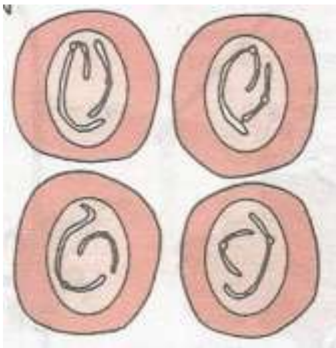
PROPHASEI

Homologous chromosomes lie alongside each other. Crossing over occurs.



TELOPHASE II

Four gametes are formed after nuclear and cytoplasmic divisions. Each contains only half the original number of chromosomes.



ANAPHASEII

A second nuclear division takes place to separate the sister chromatids.

Read the descriptions carefully and study the chart as a group. Then answer the questions that follow.

Conceptual Questions:

i. Match each phase of meiosis to the most appropriate diagram that describes it.
ii. What do you think could happen if crossing over fails to occur at Metaphase 1?
iii. What do you think could happen if each homologue in a pair fails to separate at Anaphase 1?
iv. Why is the first nuclear (i.e. Telophase 1) division necessary?
v. Why is the second nuclear division (i.e. Telophase 2) necessary?
vi. Mention any two major differences between the products of mitosis and meiosis.

Phase 3: EXPLANATION

Teacher solicits students' explanations regarding certain keywords and phenomena as it relates to their exploration and helps them justify their explanations. i.e.:

i. Differentiate between mitosis and meiosis.
ii. What are the importance of mitosis and meiosis?
iii. What are the life examples of mitosis and meiosis in plants and animals?

Teacher also provides explanations of concepts and phenomena related to the topic in a direct and formal manner. i.e.:

Meaning of Mitosis

Mitosis is a cell or nuclear division following the duplication of the chromosomes, whereby each daughter cell or nucleus has exactly the same chromosome content as the parent. In other words, mitosis is a cell division in which daughter cells have the same number of chromosomes as the parent cell.

Mitosis takes place in somatic cells, i.e., body cells that are not involved in the production of gametes. Mitosis takes place during an organism's growth, development and sexual reproduction. In plants, mitosis takes place in the terminal bud of the shoot and at the tips of the roots and shoots. In animals, mitosis occurs at growth centres which are everywhere.

Mitosis produces diploid cells. In other words, the number of chromosomes in each somatic cell of an organism is called the diploid number (2n).

Stages of Mitosis

i. Interphase
ii. Prophase
iii. Metaphase
iv. Anaphase
v. Telophase

Importance of Mitosis

(a) Mitosis promotes cell growth.
(b) It helps in the replacement or repair of damaged tissues.
(c) It serves as basis of asexual or vegetative reproduction.
(d) It produces genetically or identical offspring which are identical to the parents.
(e) Mitosis helps to maintain the diploid number of the chromosome of the cell.

Life Examples of Mitotic Processes in Plants and Animals

i. Formation of new cells in the malphighian layer of the skin.
ii. Production of red blood and white blood cells in the bone marrow.
iii. Cell division in liver.
iv. Binary fission.
v. Growth in spermatogenesis.
vi. Repair or healing of wound.

Life Examples of Mitotic Processes in Plants

i. Mitosis occurs in root tip or apex.
ii. It also occurs in stem tip or apex.
iii. It also occurs in cambium.
iv. It is found in meristems

Meaning of Meiosis

Meiosis is consists of two successive cell division with only one duplication of chromosomes. Four daughter cells are produced in meiosis. Meiosis is a reduction in cell division and the resulting four daughter cells are **haploid.**

Meiosis takes place in reproductive cells, i.e., ovules and pollen grains in plants, ovaries and testes in animals. In animals, meiosis occurs in the formation of gametes(sex cells such as eggs and spermatozoa).

The process of gamete formation is called **gametogenesis.** The process involved in the production of spermatozoa by the testes is called **spermatogenesis** while that of eggs or ova production by the ovaries is called **oogenesis.**

Stages of Meiosis

1st Meiotic Division	2nd Meiotic Division
Interphase	Prophase II
Prophase I	Metaphase II
Metaphase I	Anaphase II
Anaphase I	Telophase II
Telophase I	

Importance of Meiosis

i. It aids the formation of sperms or male gametes in animals.
ii. It aids the formation of ova (eggs) or female gametes in animals.
iii. It aids the formation of pollen grains in anthers of flowering plants.
iv. It also aids the formation of ovules in ovaries of flowering plants.

Life Examples of Meiotic Processes in Plants and Animals

Life Examples or Areas where Meiosis occurs in Plants

i. Meiosis is found in ovaries.
ii. It is also found in anthers.

Life Examples or Areas where Meiosis occurs in Animals

i. Meiosis is found in ovaries.
ii. It is also found in testes.

Differences between Mitosis and Meiosis

S/N	Mitosis	Meiosis
i.	Mitosis takes place during growth of body or somatic cells.	Meiosis takes place only in the production of gametes.
)ii.	The number of chromosomes of parent and new cells are the same.	The number of chromosomes of new cells is half the number in the parent cell (haploid number of chromosomes).
)iii.	Two offspring cells are formed.	Four offspring cells are formed.
)iv.	Chromosomes are arranged in pairs in both parents and new cells.	Chromosomes are arranged in pairs in the parent cell but new cells have only one of each homologous pair.
)v.	There is no exchange of material between the sister chromatids.	There is exchange of materials that results in variation.
)vi.	There is no formation of bivalent.	Two whole chromosomes form bivalents.
)vii.	There is no crossing over.	Crossing over occurs
)viii.	Mitosis involves only one stage of division.	Meiosis involves two stage of division.

Phase 4: ELABORATION

Teacher extends students' understanding of the concept by presenting further activities. i.e.:

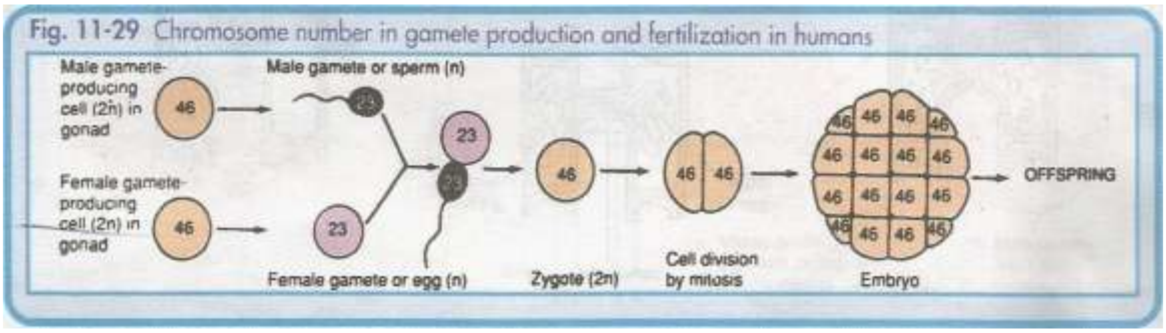
ACTIVITY 3

Aim: To Show the Changes in Chromosome Number during Gamete Production
and Fertilization in Humans.

Materials: Charts illustrating Chromosome Number in Gamete Production and

Fertilization in Humans.

Procedure: Placed before you is a chart illustrating chromosome number in gamete production and fertilization in humans.



Study the chart as a group and answer the questions that follow.

Conceptual Questions:

i. Which form of cell division is represented by letters A and B?
ii. Which form of cell division if represented by letters E and F?
iii. What do you think could be the likely consequences if the reverse is the case (i.e. if Stages E & F come before Stages A & B)?

Phase 5: EVALUATION

Teacher ensures that students demonstrate their achievement of the lesson

objectives by asking them the following questions:

i. Define mitosis in your own words.
ii. Match the stages of mitosis with their diagrams based on the given descriptions.
iii. Mention three importance of mitosis.
iv. Outline two life examples of mitotic processes in plants and animals.
v. Define meiosis in your own words.
vi. Match the stages of meiosis with their diagrams based on the given descriptions.
vii. Mention three importance of meiosis.
viii. Outline two life examples of meiotic processes in plants and animals.

ix. Mention five differences between mitosis and meiosis.

APPENDIX L

LESSON PLANS FOR THE CONTROL GROUP EXPOSED TO THE CONVENTIONALMETHOD

WEEK ONE

Method of Teaching: Lecture Method

Subject: Biology

Group: Control

Class: SS II

Number of Students: 56

Topic: Diffusion and Its Applications in Living and Non-Living Systems

Duration: 80 minutes (Double Period)

Reference Materials: Maxwell, D.A. (1998). *New Practical Biology for Senior Secondary Schools*. Ibadan: ONIBONOJE Press

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Publishers.

Michael, M.C. (2015). *Essential Biology for Senior Secondary Schools.* Ikeja: TONAD Publishers Limited.

Ramalingam, S.T. (2010). *Modern Biology for Senior Secondary Schools.* Onitsha: Africana First Publishers Plc.

Instructional Materials: Charts illustrating the experimental set-up for demonstrating diffusion in solids.

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

viii. define diffusion correctly in their own words;
ix. explain briefly at least three factors that affect the rate of diffusion;
x. describe at least one experiment to demonstrate the process of diffusion in non-living systems;
xi. mention at least two importance each of diffusion to plants and animals;
xii. outline at least three applications of diffusion in non-living conditions.

Previous Knowledge: Students are:

- familiar with the fact that matter is made up of tiny particles such as molecules or ions which are constantly moving and can exist in three states - solid, liquid and gas;
- aware of the fact that any substance can exist as a solid, a liquid or a gas depending on the conditions of temperature and pressure it is subjected to;
- conversant with the use of perfumes, room fresheners and dyes.

Introduction: Teacher introduces the lesson by giving a brief background of the topic and asking students questions relevant to their previous knowledge i.e.:

vi. What is matter?
vii. What are the states of matter?

viii. What are the basic components of all matter?
ix. What are the characteristics of each of the different forms of matter?
x. Do liquids flow faster than gases? Why?

Presentation: Teacher presents the lesson in logical steps based on the stated objectives.

Step 1: Teacher defines and explains the term 'Diffusion' i.e.:

Diffusion: Diffusion is defined as the process by which molecules or ions of a substance (i.e. gases and liquids) move from a region of high concentration to a region of low concentration until they are evenly distributed. The substance involved in diffusion may be liquid, gases or solid.

Step 2: Teacher outlines and explains briefly, the factors that affect the rate of diffusion i.e.:

Factors Affecting or Controlling Diffusion

The rate or speed of diffusion is controlled by a number of factors which include:

(5) **State of Matter**: Diffusion varies with the three states of matter. The diffusion of gases is much faster than that of liquids because the gas molecules are freer and therefore faster than liquid molecules.

(6) **Molecular Size**. The nature or the size of the molecules affects diffusion. In general, the smaller the molecules, the faster the rate of diffusion while the larger the molecules, the slower the rate of diffusion.

(7) **Differences in concentration**: For diffusion to take place in a medium, there must be differences in the concentration of the substance in two areas. This difference is known as the **concentration or diffusion gradient**. The greater the difference in the concentration of the molecules, the greater the rate of diffusion.

(8) **Temperature**: High temperature increases the speed at which molecules move. Thus, the higher the temperature, the faster the rate of diffusion.

Step 3: Teacher, with the aid of charts, describes two experiments to demonstrate the process of diffusion in non-living systems.

Aim: To Demonstrate Diffusion in Solids.

Procedure and Result: If we place a crystal of Potassium permanganate in a beaker of water and leave it to stand, the purple colour of the permanganate starts to spread outwards from the crystal. Eventually the colour spreads evenly throughout the water medium so that the water has the same shade of purple.

Aim: To Demonstrate Diffusion in Gases.

Procedure and Result: If wespray a little amount of room freshener in one corner of the classroom, the smell of the freshener starts to spread across the room until everyone in the classroom can smell the perfume.

Step 4: Teacher mentions and explains the importance of diffusion to animals and plants i.e.:

Importance of Diffusion to Animals

Diffusion plays important roles in the life of animals through the following processes:

(e) There is intake of oxygen or nutrients from mother to foetus (embryo) through placenta.

(f) Gaseous exchange in mammals occurs in the lungs during respiration.

(g) Gaseous exchange in many cells and organisms, e.g. Amoeba takes in oxygen and gets rid of carbon dioxide by diffusion.

(h) There is movement of carbon dioxide from the lung capillaries into the air sac.

Importance of Diffusion to Plants

Diffusion is important to flowering plants in the following ways:

(e) Movement of carbon dioxide through the stomata of the leaves during respiration.
(f) There is movement of carbon dioxide through the stomata into the leaves during photosynthesis.
(g) Water vapour leaving the leaves during transpiration.
(h) Movement of oxygen into the leaves through the stomata during respiration.

Step 5: Teacher outlines and explains the applications of diffusion in nature or non-living conditions i.e.:

Diffusion in Nature or Non-living Conditions

Diffusion is also very important in nature or non-living conditions through the following processes:

(e) The spread of the smell or odour of perfume from a person or a corner of a room;
(f) Diffusion of molecules (gases and liquid) in iodine, potassium permanganate and copper sulphate solutions;
(g) The spread of insecticide in a room;
(h) The spread of the smell of gases released from the anus.

Summary: Teacher summarizes the lesson by repeating the salient points in it.

Evaluation: Teacher evaluates students by asking them questions relevant to the content and lesson objectives i.e.:

v. Define diffusion in your own words.
vi. Briefly explain any three factors that affect the rate of diffusion.
vii. Describe any one experiment to demonstrate the process of diffusion in non-living systems.
viii. Mention two importance each of diffusion to plants and animals.
ix. Outline three applications of diffusion in non-living conditions.

Conclusion: Teacher ends lesson by reinforcing students accordingly and giving them notes to copy.

WEEK TWO

Method of Teaching: Lecture Method

Subject: Biology

Group: Control

Class: SS II

Number of Students: 56

Topic: Osmosis and Its Applications in Living and Non-Living Systems

Duration: 80 minutes (Double Period)

Reference Materials: Maxwell, D.A. (1998). *New Practical Biology for Senior Secondary Schools*. Ibadan: ONIBONOJE Press - Publishers.

Michael, M.C. (2015). *Essential Biology for Senior Secondary Schools.* Ikeja: TONAD Publishers Limited.

Ramalingam, S.T. (2010). *Modern Biology for Senior Secondary Schools.* Onitsha: Africana First Publishers Plc.

Instructional Materials: A chart showing Osmosis in Animal Cells; A chart showing Osmosis in Plant Cells; A chart illustrating Osmosis in a Non-Living Tissue; A chart illustrating Osmosis in a Living Tissue.

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

xi. define osmosis correctly in their own words;
xii. differentiate between a hypotonic, a hypertonic and an isotonic solution;
xiii. distinguish between endosmosis and exosmosis;
xiv. describean experiment to demonstrate the process of osmosis in non-living systems;
xv. describean experiment to demonstrate the process of osmosis in a living tissue;
xvi. explain briefly the terms osmotic pressure, osmotic potential, haemolysis, plasmolysis, turgidity and flaccidity;
xvii. draw diagrams to illustrate the effects of solutions of different strengths on animal cells;
xviii. draw diagrams to illustrate the effects of solutions of different strengths on plant cells.

Previous Knowledge: Students are:

- familiar with the concept of diffusion wherein ions or molecules of a substance move from a region where they are more concentrated to a region where they are less concentrated;
- aware of the fact that water molecules can move freely through a permeable membrane in directions and quantities that depend on the concentration gradient.

Introduction: Teacher introduces the lesson by giving a brief background of the topic and asking students questions relevant to their previous knowledge i.e.:

v. What is diffusion?
vi. What factors affect the rate of diffusion?
vii. What are the basic conditions of diffusion?
viii. Is energy generated or used up in the process of diffusion?

Presentation: Teacher presents the lesson in logical steps based on the stated objectives.

Step 1: Teacher defines and explains the term 'Osmosis' as well as mentions the conditions necessary for osmosis to occur i.e.:

Definition: Osmosis is defined as the flow of water or solvent molecules from a region of dilute or weaker solution to a region of concentrated or stronger solution through a selectively or differentially permeable membrane. It should be noted that osmosis is a special form of diffusion.

Conditions Necessary for Osmosis to TakePlace

There are three major conditions which are necessary for osmosis to take place. These are:

(d) Presence of a stronger solution, e.g. sugar or salt solution;
(e) Presence of a weaker solution, e.g. distilled water;
(f) Presence of a selectively or differentially permeable membrane.

Step 2: Teacher explains the concept of 'Living Cells as an Osmometer' wherein the difference between a hypotonic, hypertonic and isotonic solution is highlighted i.e.:

Living Cells as Osmometer

In osmosis, there are usually two solutions which are separated by a differentially permeable membrane. The weaker solution is said to be **hypotonic** while the stronger solution is said to be **hypertonic**. When both solutions have the same concentration, they are said to be **isotonic**. In living cells, when water moves across the membrane into a solution of a higher concentration, a pressure is created in the cell. This pressure is called **osmotic pressure**. The solution is said to exert a higher osmotic pressure than the weaker solution. Osmotic pressure is a force that draws in water into the cell. The pressure which a solution can potentially exert is called its **osmotic potential**. Osmoregulation is the control of fluctuations in the concentration of substances in cell fluids by special devices such as the contractile vacuoles in Amoeba and paramecium.

Step 3: Teacher briefly explains the concept of 'Cells and Osmosis' wherein the difference between a selectively permeable and semi-permeable membrane is highlighted i.e.:

Cells and Osmosis

A living cell is bound by a plasma membrane. This membrane is **selectively permeable** and allows water and certain solute molecules and ions to pass through it. As a result, the plasma membrane regulates the movement of materials between the cell and its environment. In contrast, a **semi-permeable** membrane only allows water molecules to pass through it.

Step 4: Teacher explains with the aid of a chart the concept of 'Osmosis in Animal Cells' wherein the differences between endosmosis and exosmosis in animal cells is highlighted i.e.:

Osmosis in Animal Cells

Animal cells contain mainly cytoplasm and cell organelles. In higher animals, the cells are bathed in intercellular fluid or plasma. The concentration of the solutes in these fluids is important for the well-being and functioning of the cells.

A living cell may find itself in any of the following situations:

- The fluid surrounding the cell is more concentrated than the inside of the cell. In this case, the surrounding fluid is said to be **hypertonic** to the contents of the cell. There is a net movement of water of molecules out of the cell into the surrounding. This is known as **exosmosis**. It causes the cell to shrink.
- The fluid surrounding the cell is less concentrated than the inside of the cell. Here, the surrounding fluid is said to be **hypotonic** to the contents of the cell. There is a net movement of water molecules from the surrounding fluid into the cell. This is known as **endosmosis**. It causes the cell to swell, and eventually rupture.
- The surrounding fluid and the cell contents have the same concentration. Hence, they are said to be **isotonic**. There is no net movement of water molecules in or out of the cell.

To survive and function well, the living cell and the fluid that bathes it must be **isotonic** or be able to maintain an **osmotic balance**. **Endosmosis**and **exosmosis**can lead to the eventual death of an animal.

Step 5: Teacher explains with the aid of a chart the concept of 'Osmosis in Plant Cells' wherein the differences between endosmosis and exosmosis in plant cells is highlighted i.e.:

Osmosis in Plant Cells

Plant cells have cell membranes and cell walls. The cell wall is a tough and fairly elastic structure that is **freely permeable** to all molecules and ions. The cell membrane, however, is **selectively permeable**. Unlike an animal, most of the space in a plant cell is occupied by a large central vacuole that contains **cell sap**. Cell sap is complex mixture of solute. It has a high concentration and tends to draw in water into the cell from the surroundings by osmosis.

When **endosmosis** occurs, water flows into the vacuole of a plant cell, causing the cell to swell. The cell, however, does not rupture because, although the cell wall stretches to a certain extent, it is tough and does not break. It also prevents the cell membrane from expanding. A high pressure builds up inside the cell and makes it **turgid**.

When **exosmosis** occurs, water flows out of the vacuole of the plant cell into the surroundings. As a result, the vacuole shrinks and eventually pulls the cytoplasm from the cell wall. This process is known as **plasmolysis**.

Step 6: Teacher, with the aid of a chart, describes an experiment to demonstrate the process of osmosis in a non-living tissue i.e.:

Aim: To Demonstrate Osmosis in a Non-living System.

Procedure and Result: Set up the apparatus as shown in the chart. Mark the level of sugar solution in thistle funnel A and water in thistle funnel B. Allow the experiment to remain for 2-3 hours. At the end of the experiment, the volume of sugar solution will rise in the thistle funnel A while the water level in the beaker will reduce. At the same time, the volume of water in funnel B and beaker remain at the same level.

Conclusion: The rise of sugar solution in thistle funnel A and a decrease in the water level in the beaker show that osmosis has taken place.

Step 7: Teacher, with the aid of a chart, describes an experiment to demonstrate the process of osmosis in a living tissue i.e.:

Aim: To Demonstrate Osmosis in a Living Tissue.

Procedure and Result: Set up the apparatus as shown in the chart. Mark the level of sugar solution in yam tissue A and water in yam tissue B. Allow the experiment to remain for 4-6 hours. At the end of the experiment, it is observed that the level of sugar solution in A has risen resulting in a decrease in water level in the beaker (or Petri-dish) while the water level in B remains the same both in the tuber and in the Petri-dish.

Conclusion: Since the sugar solution has risen in yam tissue A, it shows that osmosis has taken place.

Step 8: Teacher defines and explains the concepts of 'Haemolysis', 'Turgidity', 'Plasmolysis' and 'Flaccidity' as they apply or relate to osmosis i.e.:

Haemolysis: Haemolysis is defined as the process by which red blood cells or corpuscles become split or burst as a result of too much water passing into it. This situation will occur when the red blood cell is placed in a weaker or hypotonic solution where the red blood cell takes in water and become swollen and may even burst.

Turgidity: Turgidity is defined as the condition in which cells absorb plenty of water up to a point where the cells is fully stretched. At this point, the cell is said to be **turgid**. Turgidity occurs when a plant is placed in a hypotonic solution (e.g. distilled water). As a result of the fact that the cytoplasm solution is stronger than the water, the cell absorbs water and becomes turgid. Turgidity is useful to land plants because it makes them stand erect and gives support to the stem, leaves, flowers and guards cells. It also makes herbaceous plants look firm.

Plasmolysis: Plasmolysis is defined as the outward movement or flow of water from living cells when they are placed in a hypertonic solution. Plasmolysis is often regarded as the opposite of osmosis. The process of plasmolysis involves the withdrawal of water from living cells up to the extent that it will result in the pulling away of the cytoplasm from the cell membrane or cell wall. As a result of this, the cytoplasm will shrink and the whole cell will collapse. When this happens, the cells are said to be **plasmolysed**. This will eventually lead to wilting or death of the plant.

Flaccidity: Flaccidity is defined as the condition in which plants lose water to their surroundings faster than they can absorb. When plant looses more water, it is said to be **flaccid**. Flaccidity normally occurs when there is no water in the soil or during drought. Such continuous loss of water to the surroundings may cause the plant to wilt or even die if it continues for a very long time.

Summary: Teacher summarizes the lesson by repeating the salient points in it.

Evaluation: Teacher evaluates students by asking them questions relevant to the content and lesson objectives i.e.:

ix. Define osmosis in your own words.
x. Differentiate between a hypotonic, a hypertonic and an isotonic solution.
xi. Distinguish between endosmosis and exosmosis.
xii. Describean experiment to demonstrate the process of osmosis in non-living systems;
xiii. Describean experiment to demonstrate the process of osmosis in a living tissue;

xiv. Briefly explain the terms osmotic pressure, osmotic potential, haemolysis, plasmolysis, turgidity and flaccidity.
xv. Draw diagrams to illustrate the effects of solutions of different strengths on animal cells.
xvi. Draw diagrams to illustrate the effects of solutions of different strengths on plant cells.

Conclusion: Teacher ends lesson by reinforcing students accordingly and giving them notes to copy.

WEEK THREE

Method of Teaching: Lecture Method

Subject: Biology

Group: Control

Class: SS II

Number of Students: 56

Topic: Active Transport, Endocytosis and Exocytosis and their Applications

Duration: 80 minutes (Double Period)

Reference Materials: Maxwell, D.A. (1998). *New Practical Biology for Senior Secondary Schools*. Ibadan: ONIBONOJE Press

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Publishers.

Michael, M.C. (2015). *Essential Biology for Senior Secondary Schools.* Ikeja: TONAD Publishers Limited.

Ramalingam, S.T. (2010). *Modern Biology for Senior Secondary Schools.* Onitsha: Africana First Publishers Plc.

Instructional Materials: Achart illustrating active transport between human red blood cells and plasma; a chart showing Endocytosis in a white blood cell;a chart illustrating Exocytosis in a gland cell.

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

xi. define active transport correctly in their own words;
xii. describe the process of active transport between the human red blood cells and plasma;
xiii. mention at least two applications of active transport in living systems;
xiv. differentiate between Endocytosis and Exocytosis;
xv. explain briefly the two types of Endocytosis;
xvi. mention at least one application each of Endocytosis and Exocytosis in living systems;
xvii. distinguish between passive and active processes of transport across the plasma membrane;
xviii. outline at least three importance of transport across the plasma membranes of plant and animal cells.

Previous Knowledge: Students are:

- familiar with the concept of diffusion and osmosis wherein molecules move from one medium to another depending on their concentration gradients;

- aware of the fact that diffusion and osmosis can occur in living and non-living systems;
- conversant with the fact that both diffusion and osmosis are passive processes and do not require energy;
- familiar with the basic differences between diffusion and osmosis.

Introduction: Teacher introduces the lesson by giving a brief background of the topic and asking students questions relevant to their previous knowledge i.e.:

v. What are the major similarities between diffusion and osmosis?
vi. What are the basic differences between diffusion and osmosis?
vii. Does diffusion apply specifically to water molecules?
viii. What are the reasons for your answer?

Presentation: Teacher presents the lesson in logical steps based on the stated objectives.

Step 1: Teacher defines and explains the concept of 'Active Transport' i.e.:

Active Transport: Active transport is defined as the movement of solute molecules and ions across a membrane from a region of low concentration to a region of high concentration with resultant energy consumption.

Step 2: Teacher, with the aid of a chart, explains the process of active transport between the human red blood cells and plasma i.e.:

Active Transport between Human Red Blood Cell and Plasma

Sodium ions are in low concentration in a human red blood cell and in high concentration in the plasma. Yet, sodium ions are transported out of the cell into the plasma, against the existing concentration gradient. In a similar manner, potassium ions are transported from the plasma into the cell. This process is known as active transport and always requires energy. It often occurs against a concentration gradient as in the above example.

Step 3: Teacher mentions and explains the applications of active transport in living systems i.e.:

Applications of Active Transport in Living Systems

Active transport is particularly important in:

iii. cells lining the gut, where absorption of digested food substances occurs; and
iv. cells of the kidney tubules, where reabsorption occurs.

Cells carrying out active transport have:

- numerous mitochondria;
- a high concentration of ATP (immediate energy store); and
- a high cellular respiratory rate.

Step 4: Teacher defines and explains, with the aid of a chart, the terms 'Endocytosis' and 'Exocytosis', pointing out the major differences between them i.e.:

Endocytosis: Endocytosis is defined the process by which the plasma membrane of a cell folds inwards to ingest or take up material into the cell in a vesicle or vacuole with resultant energy consumption.

Exocytosis: Exocytosis is defined as the process by which materials are transported out of a cell by means of vesicles or an extension of the plasma membrane with resultant energy consumption.

Step 5: Teacher outlines and explains the two types of Endocytosis i.e.:

Types of Endocytosis

Both **Phagocytosis** and **Pinocytosis** are endocytotic processes.

iii. The tern **'Phagocytosis'** is used when solid materials are taken into the cell by engulfing them.
iv. The term **'Pinocytosis'** is used when liquid materials are taken into the cell.

Step 6: Teacher mentions and explains the applications of Endocytosis and Pinocytosis in living systems i.e.:

Applications of Endocytosis and Pinocytosis in Living Systems

- An*Amoeba* captures its food and a white blood cell engulfs bacteria that invade the body by Phagocytosis (Endocytosis).
- Hormones and enzymes are secreted from the cells in which they are made by reverse Pinocytosis (Exocytosis).

Step 7: Teacher explains the differences between passive and active processes of transport across the plasma membrane i.e.:

Passive and Active Processes of Transport across the Plasma Membrane

There are four methods of entry into or exit from cells. These are **diffusion**, **osmosis**, **active transport** and **Endocytosis** or **Exocytosis**.

- **Diffusion and Osmosis** are passive processes and do not require energy. They only depend on a concentration gradient.
- **Active Transport and Endocytosis or Exocytosis** are active processes and do require energy. They do not depend on a concentration gradient.

Step 8: Teacher outlines and explains the importance of transport across the plasma membranes of plant and animal cells i.e.:

Importance of Transport across the Plasma Membrane

Transport across the plasma membranes of plant and animal cells is important to cells for:

iv. obtaining oxygen and nutrients (to supply energy and raw materials for syntheses);
v. excreting toxic substances (result of metabolic activities); and
vi. maintaining a suitable pH and solute concentration (for enzyme activity).

Summary: Teacher summarizes the lesson by repeating the salient points in it.

Evaluation: Teacher evaluates students by asking them questions relevant to the content and lesson objectives i.e.:

ix. Define active transport in your own words.
x. Describe the process of active transport between the human red blood cells and plasma.
xi. Mention two applications of active transport in living systems.
xii. Differentiate between Endocytosis and Exocytosis.
xiii. Briefly explain the two types of Endocytosis.
xiv. Mention one application each of Endocytosis and Exocytosis in living systems.
xv. Distinguish between passive and active processes of transport across the plasma membrane.
xvi. Outline three importance of transport across the plasma membranes of plant and animal cells.

Conclusion: Teacher ends lesson by reinforcing students accordingly and giving them notes to copy.

Method of Teaching: Lecture Method

Subject: Biology

Group: Control

WEEK FOUR

Method of Teaching: Lecture Method

Subject: Biology

Group: Control

Class: SS II

Number of Students: 56

Topic: Catabolic Processes: Cellular Respiration

Duration: 80 minutes (Double Period)

Reference Materials: Maxwell, D.A. (1998). *New Practical Biology for Senior Secondary Schools*. Ibadan: ONIBONOJE Press

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Publishers.

Michael, M.C. (2015). *Essential Biology for Senior Secondary Schools.* Ikeja: TONAD Publishers Limited.

Ramalingam, S.T. (2010). *Modern Biology for Senior Secondary Schools.* Onitsha: Africana First Publishers Plc.

Instructional Materials: A chart showing the main steps in cellular respiration; a chart illustrating an experimental set-up to show that a mouse respires aerobically; a chart illustrating an experimental set-up to show that in the absence of oxygen, yeast respires anaerobically; achart illustrating an experimental set-up to show that heat is produced during cellular respiration.

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

xi. define catabolism and cellular respiration in their own words;
xii. explain with the aid of chemical equations the two types of cellular respiration;
xiii. explain briefly how energy is released from food in a living cell;
xiv. perform an experiment to show that carbon dioxide and water vapour are given off when food is burnt;
xv. mention at least three differences between aerobic and anaerobic respiration;
xvi. outline at least three similarities between aerobic and anaerobic respiration;

xvii. describe one experiment each to demonstrate aerobic and anaerobic respiration in named organisms;

xviii. describe an experiment to show that heat energy is given out during cellular respiration.

Previous Knowledge: Students are:

- familiar with the concept of respiration as the exchange of gases (oxygen and carbon dioxide) between organisms and their environment;
- aware of the fact that respiration is a fundamental characteristic of all living things;
- conversant with the fact that the purpose of respiration is to oxidize food substances in order to release energy which is used for all life processes.

Introduction: Teacher introduces the lesson by giving a brief background of the topic and asking students questions relevant to their previous knowledge i.e.:

vii. What is respiration?

viii. What are the gases we humans breathe in and breathe out?

ix. It is often said that plants take in carbon dioxide and give out oxygen during respiration. Is that scientifically correct? Why?

x. Why do living organisms respire?

xi. Differentiate between breathing and respiration.

xii. Differentiate between respiration and combustion.

Presentation: Teacher presents the lesson in logical steps based on the stated objectives.

Step 1: Teacher defines and explains the terms 'Catabolism' and 'Cellular Respiration' i.e.:

Catabolism: Catabolism is defined as the breaking down of complex organic molecules into simple substances coupled with the release of energy. Examples of catabolic processes in the body are respiration, fermentation and digestion.

Cellular Respiration: Cellular respiration involves the chemical activities of the cells in which glucose is broken down by a series of reactions controlled by enzymes to release energy. The energy released is stored in adenosine triphosphate (ATP). ATP is the form in which energy is carried, stored and used by all living cells for the various metabolic processes. The entire purpose of cellular respiration is to generate energy for various metabolic processes in all organisms.

Step 2: Teacher mentions and explains the two types of cellular respiration using chemical equations i.e.:

Types of Cellular Respiration

There are two main types of cellular Respiration. These are **aerobic** and **anaerobic** respiration

Aerobic Respiration: Aerobic Respiration is the type of respiration which requires oxygen to break down glucose (substrates) into water, carbon dioxide and energy (ATP). Aerobic respiration can be represented by the chemical equation below:

$C_6H_{12}O_6$	+	$6O_2$	→	$6CO_2$	+	$6H_2O$	+	Energy
(Glucose)		(Oxygen)		(Carbon dioxide)		(water)		(ATP)

Anaerobic Respiration: Anaerobic Respiration is the type of which does not require the presence of oxygen to provide energy. During anaerobic respiration, glucose is broken down to yield carbon dioxide, alcohol(ethanol) and energy. The anaerobic respiration can be represented by a chemical equation as :

$C_6H_{12}O_6$	→	$2C_2H_5OH$	+	$2CO_2$	+	Energy
(Glucose)		(Alcohol)		(Carbon dioxide)		(ATP)

Step 3: Teacher, with the aid of a chart, explains how energy is released from food in a living cell i.e.:

Release of Energy from Food

When food is burnt in the laboratory, the following reaction occurs:

Food + Oxygen → Carbon dioxide + Water + Energy

Oxygen is necessary for food to burn. It is, therefore, an oxidation reaction. The complex food substance is broken down to liberate the simple molecules, carbon dioxide and water, and energy. The reaction is rapid and heat is given off in large amounts in one big step.

Scientists have shown that food is also burnt in a similar way in living cells. The main food that is burnt in cells is glucose. This oxidation process which produces energy, carbon dioxide and water is summarized below:

$C_6H_{12}O_6$ + $6O_2$ → $6CO_2$ + $6H_2O$ + Energy
(Glucose) (Oxygen) (Enzymes) (Carbon dioxide) (Water)
(ATP)

However, the energy is not released in one big step as shown in the above reaction, but in a series of small steps which are catalysed by enzymes. The energy that is released, bit by bit, is stored in adenosine triphosphate (ATP) molecules. The oxidation of glucose to release energy in this manner is known as cellular respiration. It occurs in the mitochondria of all living cells.

During Cellular respiration, one molecule of the **6-Carbon glucose** is broken down into two molecules of the **3-carbon Pyruvic acid** by enzymes in the cytoplasm of the cell. These reactions do not require oxygen. Each molecule of Pyruvic acid is oxidized completely to carbon dioxide and water in the mitochondrion. This latter series of reactions is known as the Kreb's Cycle. Most of the ATP molecules is formed in this cycle. A total of 38 ATP molecules are formed when one molecule of glucose is completely oxidized.

When needed, lipids and proteins are broken down to small molecules and enter the Kreb's cycle at various points.

Step 4: Teacher describes an experiment to show that Carbon dioxide and water vapour are given off when food is burnt i.e.:

Aim: To Show that Carbon dioxide and Water Vapour are Given Off when Food is Burnt.

Procedure and Results: Heat some sugar in a hard glass tube and pass the products formed through white anhydrous Copper (II) sulphate and through lime water. The white Copper (II) sulphate turns blue, while lime water turns chalky. These reactions indicate that the products are water vapour and Carbon dioxide respectively.

Step 5: Teacher mentions and explains the differences between aerobic and anaerobic respiration i.e.:

Differences between Aerobic and Anaerobic Respiration

Aerobic Respiration	Anaerobic Respiration
(f) Oxygen is required for oxidation.	Oxygen is not required for oxidation.
(g) By-products are water and carbon dioxide.	By-products are alcohol or lactic acid.
(h) More energy is released.	Less energy is released.
(i) It takes place in mitochondria.	It takes place in cytoplasm.
(j) Water is given off as by-product.	Alcohol is given as by-product.

Step 6: Teacher outlines and explains the similarities between aerobic and anaerobic respiration i.e.:

Similarities between Aerobic and Anaerobic respiration

(f) Both aerobic and anaerobic respirations lead to the release of energy.
(g) Both occur in plant and animal cells.
(h) Both processes require enzymes to speed up the reactions.
(i) Both processes lead to the generation of heat.
(j) Both give off carbon dioxide as by product.

Step 7: Teacher, with the aid of charts, describes one experiment each to demonstrate aerobic and anaerobic respiration in named organisms i.e.:

Aim: To Show that A Mouse Respires Aerobically.

Procedure and Results: Set up the apparatus as shown in the chart. After some time, the lime water in the right hand test-tube turns milky. This indicates the presence of Carbon dioxide, which shows that the mouse is respiring aerobically. Set up a control experiment in the same way but without the mouse. The lime water remains the same, indicating the absence of Carbon dioxide.

Aim: To Show that In the Absence of Oxygen, Yeast Respires Anaerobically.

Procedure and Results: Make a glucose-yeast suspension by adding yeast pellets to a 10% glucose solution. Place the suspension in a conical flask and cover the suspension in a thin layer of paraffin oil to exclude atmospheric oxygen as illustrated in the chart. Maintain the apparatus at 37^{0}C for several hours. It is noticed that the lime water appears milky in the test-tube, indicating the liberation of Carbon dioxide.

Step 8: Teacher, with the aid of a chart, describes an experiment to show that heat energy is given out during cellular respiration i.e.:

Aim: To Show that Heat Energy is Given Out during Cellular Respiration.

Procedure and Results: Set up the apparatus as shown in the chart. Sprinkle a few drops of 5% Formalin over the seeds in the two flasks to prevent fungal or bacterial growth. After a few hours, note the temperature in each flask. There will be an increase in temperature in the flask containing the germinating seeds. This shows that heat energy comes from the respiring germinating seeds. The flask containing the dry seeds does not show any marked temperature change since dry seeds do not respire as vigorously as germinating seeds.

Summary: Teacher summarizes the lesson by repeating the salient points in it.

Evaluation: Teacher evaluates students by asking them questions relevant to the content and lesson objectives i.e.:

ix. Define catabolism and cellular respiration in your own words.
x. With the aid of chemical equations, explain the two types of cellular respiration.
xi. Briefly explain how energy is released from food in a living cell.
xii. Describe an experiment to show that carbon dioxide and water vapour are given off when food is burnt.
xiii. Mention three differences between aerobic and anaerobic respiration.
xiv. Outline three similarities between aerobic and anaerobic respiration.
xv. Describe an experiment each to demonstrate aerobic and anaerobic respiration in named organisms.
xvi. Describe an experiment to show that heat energy is given out during cellular respiration.

Conclusion: Teacher ends lesson by reinforcing students accordingly and giving them notes to copy.

WEEK FIVE

Method of Teaching: Lecture Method

Subject: Biology

Group: Control

Class: SS II

Number of Students: 56

Topic: Anabolic Processes: Photosynthesis

Duration: 80 minutes (Double Period)

Reference Materials: Maxwell, D.A. (1998). *New Practical Biology for Senior Secondary Schools*. Ibadan: ONIBONOJE Press -
Publishers.

Michael, M.C. (2015). *Essential Biology for Senior Secondary Schools.* Ikeja: TONAD Publishers Limited.

Ramalingam, S.T. (2010). *Modern Biology for Senior Secondary Schools.* Onitsha: Africana First Publishers Plc.

Instructional Materials: A chart illustrating Adaptation of Leaf Structure for Photosynthesis; Real Leaves from Dicotyledonous and Monocotyledonous Plants; a chart illustrating the fate of photosynthesis.

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

xii. define anabolism in their own words;
xiii. outline at least three examples of anabolic processes;
xiv. explain briefly the main features of photosynthesis in four steps;
xv. explain the chemistry of photosynthesis with the aid of simple chemical equations;
xvi. describe an experiment to show that starch is produced during photosynthesis;
xvii. draw the section of a leaf to show its adaptations for photosynthesis;
xviii. perform an experiment to show that chlorophyll is necessary for photosynthesis
xix. explain briefly the fate of photosynthetic products;
xx. mention at least three importance of photosynthesis to life.

Previous Knowledge: Students are:

- aware of the fact that most plants are green and all green plants can manufacture their own food via photosynthesis;

- conversant with the fact that all animals cannot manufacture their own food but have to feed on plant materials to survive, grow and reproduce.

Introduction: Teacher introduces the lesson by giving a brief background of the topic and asking students questions relevant to their previous knowledge i.e.:

vii. Why are most plants in our environment green?
viii. How do plants make their food?
ix. Why do plants need sunlight to make their food?
x. In what ways do you think organic molecules manufactured by plants are utilized by them?
xi. Why do you think animals need to feed on plants or plant materials?
xii. In what ways do you think animals utilize the organic molecules they derive from plants?

Presentation: Teacher presents the lesson in logical steps based on the stated objectives.

Step 1: Teacher defines and explains the term 'Anabolism' i.e.:

Anabolism: Anabolism is defined as the building up of complex organic molecules from simple ones in a biological system. In anabolic process, energy is usually consumed because some forms of energy are required first to break the old molecules before building up the complex ones.

Step 2: Teacher outlines and explains the examples of anabolic processes i.e.:

Common examples of anabolic processes are:

(f) The formation of glycogen from glucose.
(g) The formation of starch from glucose.
(h) The formation of proteins from amino acids.
(i) The formation of fats and oils from fatty acids and glycerol.
(j) Photosynthesis in green plants.

Step 3: Teacher defines photosynthesis and explains the main features of photosynthesis in four steps i.e.:

PHOTOSYNTHESIS

Photosynthesis is the process by which green plants manufacture food. Photosynthesis is important not only to plants themselves but also to animals, which depend on plants for food. The main features of photosynthesis are as follows:

- Photosynthesis takes place in the chloroplasts of plant cells, in the presence of sunlight.
- The raw materials of the process are the low-energy containing inorganic compounds, carbon dioxide and water.
- The final products of the process are high-energy containing sugars (organic compounds). Oxygen is given off as a waste product.
- The energy needed to drive this anabolic process comes from the sunlight absorbed by chlorophyll, the green pigment found in chloroplasts.

The gases, carbon dioxide and oxygen, move in and out between the surrounding air and leaves through stomatal openings on the leaf surfaces. Water from the soil enters the root hairs, by osmosis. From the root hairs, it is conducted upwards through the stem to the leaves.

Most of the sugars produced are changed into starch in the leaf cells. They are stored in this insoluble form until night-time. Then, the starch is converted back into sugars (soluble form) to be transported to other parts of the plant where they are needed. This movement of sugars is known as **translocation**.

In the cells, the sugars are used as a source of energy. Some plants have special storage organs where the sugar is converted back to starch to be stored for long periods of time. The storage organs may be roots, stems, fruits or seeds.

Step 4: Teacher explains the chemistry of photosynthesis with the aid of simple chemical equations i.e.:

Chemistry of Photosynthesis

The chloroplasts contain the green pigment **chlorophyll**, which absorbs light energy from sunlight. This energy is used for the splitting or **photolysis** of water molecules to give **hydrogen (H)** components and **hydroxide (OH)** components.

(5) $4H_2O \rightarrow 4H + 4OH$

The **OH** components undergo further reactions to produce water and oxygen.

(6) $4OH \rightarrow 2H_2O + O_2$

The **H** components undergo a series of reactions in which they reduce carbon dioxide to form sugar.

(7) $CO_2 + 4H \rightarrow CH_2O + H_2O$

The above reactions are catalysed by enzymes. The overall reaction of photosynthesis can be summed up as follows:

(8) $2H_2O + CO_2 \xrightarrow[\text{chlorophyll}]{\text{energy, enzymes}} CH_2O + H_2O + O_2$

Since the first sugar formed during photosynthesis is glucose ($C_6H_{12}O_6$), the simplified net reaction of photosynthesis is given more specifically as follows:

$$6H_2O + 6CO \xrightarrow[\text{chlorophyll}]{\text{energy, enzymes}} C_6H_{12}O_6 + 6O_2$$

NOTE: During photosynthesis, the oxygen liberated comes **only** from water molecules, not from carbon dioxide.

From the above, we see that photosynthesis consists of two essential stages:

- the first is the splitting of water molecules; and
- the second is the reduction of carbon dioxide molecules.

Only the first stage needs light; the second stage can occur in the dark. Therefore, these two stages are respectively are known as **light** and **darkstages** of photosynthesis. The dark stage is dependent on the light stage, since the reduction of carbon dioxide is brought about by the hydrogen components produced by the splitting of water molecules in the light stage.

Step 5: Teacher describes an experiment to show that starch is produced during

photosynthesis i.e.:

Aim: To Show that Starch is Produced during Photosynthesis.

Procedure and Results: A leaf is plucked after being exposed to sunlight for a few hours Place leaf in boiling water for half a minute to kill it. Decolorize the leaf by placing it in hot alcohol in a water bath. Dip decolorized leaf in hot water to soften it. Place leaf on tile and add iodine solution to it. When iodine is added, leaf becomes blue black if starch is present. Leaf is stained light brown (iodine colour) if starch is absent.

Step 6: Teacher explains, with the aid of a chart, the main structural adaptations of a leaf

to photosynthesis i.e.:

Leaf as a Photosynthetic Organ

Although all the parts of the plant can carry out photosynthesis, the leaves are the main photosynthetic organs. As such, the structure of a leaf is specially adapted for carrying out this function.

Structure	**Adaptation**
Leaf Stalk	Able to hold leaf blade in the best position to receive maximum amount of sunlight.
Leaf Blade	Large surface area for receiving sunlight; thin structure to ensure that the carbon dioxide that enters the leaf can rapidly reach each leaf cell by diffusion.
Stomata	Present on leaf surface in large numbers to allow entry and exit of gases and water vapour from leaf.
Intercellular Spaces	Present throughout leaf, linking the interior of leaf to the external environment, enabling diffusion and distribution of gases and water vapour from and to all photosynthetic cells.
Transport Tissue	Well distributed throughout leaf to bring water to each photosynthetic cell and remove manufactured food from it.
Mesophyll Tissue	Cells especially at the upper surface, contain numerous chloroplasts to carry out photosynthesis.

Step 7: Teacher describes an experiment to show that chlorophyll is necessary for during photosynthesis i.e.:

Aim: To Show that Chlorophyll is Necessary for Photosynthesis.

Procedure and Results: Take a variegated leaf (a leaf from *Coleus*, *Croton* or *Acalypha* plant) that has been exposed to sunlight for a few hours. Draw a diagram to show the distribution of the green colour of the leaf. Then test the leaf for starch. It will be found that only the green parts contain starch. This shows that starch formation cannot occur in the absence of chlorophyll.

Step 8: Teacher explains, with the aid of a chart, the fate of photosynthetic products in plants and animals i.e.:

Fate of photosynthetic Products

The energy-rich products of photosynthesis(food) are used by plants

- as a source of energy for their activities; and
- for producing most of the materials needed by them for growth and reproduction.

For example, glucose, an important photosynthetic product, is broken down in plants cells to provide energy. The cells also use glucose to build up many organic that the plant needs. Excess glucose is converted to substances, such as sucrose, starch and oils, which are then stored in various parts of the plant.

When a plant is eaten by an animal, the digestible food substances in the plant are broken down to their basic units and absorbed into the animal’s body. In the cells of the animal, these substances are used for proving energy and for building-up the many organic compounds that the animal needs. Excess food materials may be broken down and excreted or converted to storage substances such as fats and glycogen.

Step 9: Teacher mentions and explains the importance of photosynthesis to life i.e.:

Importance of Photosynthesis to Life

Photosynthesis is very important in food cycles as it is the only process that can tap the sun’s enormous energy supply. Animals and other heterotrophs cannot make use of the sun’s energy and simple substances to manufacture energy-rich food. Therefore, all heterotrophs are directly or indirectly dependent on green plants for food.

Photosynthesis also helps to purify the environment by removing carbon dioxide from the environment and adding oxygen to it. If not, the atmosphere will become saturated with carbon dioxide released during respiration, decomposition and combustion.

Summary: Teacher summarizes the lesson by repeating the salient points in it.

Evaluation: Teacher evaluates students by asking them questions relevant to the content and lesson objectives i.e.:

x. Define anabolism in your own words.
xi. Outline three examples of anabolic processes.

xii. Briefly explain the main features of photosynthesis in four steps.
xiii. With the aid of simple chemical equations, explain the chemistry of photosynthesis.
xiv. Describe an experiment to show that starch is produced during photosynthesis.
xv. Describe an experiment to show that chlorophyll is necessary for photosynthesis.
xvi. With the aid of a diagram, describe the structural adaptations of a leaf to photosynthesis.
xvii. Briefly explain the fate of photosynthetic products.
xviii. Mention three importance of photosynthesis to life.

Conclusion: Teacher ends lesson by reinforcing students accordingly and giving them notes to copy.

WEEK SIX

Method of Teaching: Lecture Method

Subject: Biology

Group: Control

Class: SS II

Number of Students: 56

Topic: Mitosis and Meiosis and their Applications

Duration: 80 minutes (Double Period)

Reference Materials: Maxwell, D.A. (1998). *New Practical Biology for Senior Secondary Schools*. Ibadan: ONIBONOJE Press

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Publishers.

Michael, M.C. (2015). *Essential Biology for Senior Secondary Schools.* Ikeja: TONAD Publishers Limited.

Ramalingam, S.T. (2010). *Modern Biology for Senior Secondary Schools.* Onitsha: Africana First Publishers Plc.

Instructional Materials: A Chart Showing the Different Stages of Mitosis; A Chart Showing the Different Stages of Meiosis.

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

xi. define mitosis and meiosis in their own words;
xii. match correctly the stages of mitosis with their diagrams based on given descriptions;
xiii. mention at least three importance of mitosis;
xiv. outline at least two life examples of mitotic processes in plants and animals;
xv. match correctly the stages of meiosis with their diagrams based on given descriptions;
xvi. mention at least three importance of meiosis;
xvii. outline at least two life examples of meiotic processes in plants and animals;
xviii. mention at least five differences between mitosis and meiosis.

Previous Knowledge: Students are:

- aware that all living organisms are made up of cells and that they grow by the multiplication of and enlargement of their cells;
- conversant with the fact that all unicellular organisms reproduce by different forms of cell division.

Introduction: Teacher introduces the lesson by giving a brief background of the topic and asking students questions relevant to their previous knowledge i.e.:

vi. How is it possible for a cell to multiply itself?
vii. In how many different ways can a cell divide?
viii. There are different types of cells in the bodies of plants and animals. Do you think all these specialized cells have the ability to multiply?
ix. What are the different forms of cell division found in unicellular organisms such as bacteria, amoeba, paramecium, euglena and yeast?

x. How do living things grow? Do you think their cells just multiply or just enlarge?

Presentation: Teacher presents the lesson in logical steps based on the stated objectives.

Step 1: Teacher defines and explains the term ‘Mitosis’.

Mitosis: Mitosis is a cell or nuclear division following the duplication of the chromosomes, whereby each daughter cell or nucleus has exactly the same chromosome content as the parent. In other words, mitosis is a cell division in which daughter cells have the same number of chromosomes as the parent cell.

Mitosis takes place in somatic cells, i.e., body cells that are not involved in the production of gametes. Mitosis takes place during an organism’s growth, development and sexual reproduction. In plants, mitosis takes place in the terminal bud of the shoot and at the tips of the roots and shoots. In animals, mitosis occurs at growth centres which are everywhere.

Mitosis produces diploid cells. In other words, the number of chromosomes in each somatic cell of an organism is called the diploid number (2n).

Step 2: Teacher outlines and explains, with the aid of a chart, the five stages or phases of mitosis i.e.:

Stages of Mitosis

vi. Interphase
vii. Prophase
viii. Metaphase
ix. Anaphase
x. Telophase

Step 3: Teacher mentions and explains three importance of mitosis i.e.:

Importance or Role of Mitosis

(f) Mitosis promotes cell growth.
(g) It helps in the replacement or repair of damaged tissues.
(h) It serves as basis of asexual or vegetative reproduction.
(i) It produces genetically or identical offspring which are identical to the parents.
(j) Mitosis helps to maintain the diploid number of the chromosome of the cell.

Step 4: Teacher outlines and explains the life examples of mitotic processes in plants and animals i.e.:

Life Examples of Mitotic Processes in Animals

vii. Formation of new cells in the malphighian layer of the skin.
viii. Production of red blood and white blood cells in the bone marrow.
ix. Cell division in liver.
x. Binary fission.
xi. Growth in spermatogenesis.
xii. Repair or healing of wound.

Life Examples of Mitotic Processes in Plants

v. Mitosis occurs in root tip or apex.
vi. It also occurs in stem tip or apex.
vii. It also occurs in cambium.
viii. It is found in meristems

Step 5: Teacher defines and explains the term 'meiosis' i.e.:

Meiosis: Meiosis consists of two successive cell divisions with only one duplication of chromosomes. Four daughter cells are produced in meiosis. Meiosis is a reduction in cell division and the resulting four daughter cells are **haploid.**

Meiosis takes place in reproductive cells, i.e., ovules and pollen grains in plants, ovaries and testes in animals. In animals, meiosis occurs in the formation of gametes(sex cells such as eggs and spermatozoa).

The process of gamete formation is called **gametogenesis.** The process involved in the production of spermatozoa by the testes is called **spermatogenesis** while that of eggs or ova production by the ovaries is called **oogenesis.**

Step 6: Teacher outlines and explains, with the aid of a chart, the stages or phases of meiosis i.e.:

Stages of Mitosis

1^{st} Meiotic Division	2^{nd} Meiotic Division
Interphase	Prophase II

Prophase I	Metaphase II
Metaphase I	Anaphase II
Anaphase I	Telophase II
Telophase I	

Step 7: Teacher mentions and explains the importance of meiosis i.e.:

Importance of Meiosis

v. It aids the formation of sperms or male gametes in animals.
vi. It aids the formation of ova (eggs) or female gametes in animals.
vii. It aids the formation of pollen grains in anthers of flowering plants.
viii. It also aids the formation of ovules in ovaries of flowering plants.

Step 8: Teacher outlines and explains the life examples of meiotic processes in plants and animals i.e.:

Life Examples or Areas where Meiosis occurs in Plants

iii. Meiosis is found in ovaries.
iv. It is also found in anthers.

Life Examples or Areas where Meiosis occurs in Animals

iii. Meiosis is found in ovaries.
iv. It is also found in testes.

Step 9: Teacher mentions and explains the differences between mitosis and meiosis i.e.:

Differences between Mitosis and Meiosis

S/N	Mitosis	Meiosis
i.	Mitosis takes place during growth of body or somatic cells.	Meiosis takes place only in the production of gametes.
)ii.	The number of chromosomes of parent and new cells are the same.	The number of chromosomes of new cells is half the number in the parent cell (haploid number of chromosomes).
)iii.	Two offspring cells are formed.	Four offspring cells are formed.
0) v.	Chromosomes are arranged in pairs in both parents and new	Chromosomes are arranged in pairs in the parent cell but new cells

	cells.	have only one of each homologous pair.
1) .	There is no exchange of material between the sister chromatids.	There is exchange of materials that results in variation.
2) i.	There is no formation of bivalent.	Two whole chromosomes form bivalents.
3) ii.	There is no crossing over.	Crossing over occurs
4) iii .	Mitosis involves only one stage of division.	Meiosis involves two stage of division.

Summary: Teacher summarizes the lesson by repeating the salient points in it.

Evaluation: Teacher evaluates students by asking them questions relevant to the content and lesson objectives i.e.:

x. Define mitosis in your own words.
xi. Match the stages of mitosis with their diagrams based on the given descriptions.
xii. Mention three importance of mitosis.
xiii. Outline two life examples of mitotic processes in plants and animals.
xiv. Define meiosis in your own words.
xv. Match the stages of meiosis with their diagrams based on the given descriptions.
xvi. Mention three importance of meiosis.
xvii. Outline two life examples of meiotic processes in plants and animals.
xviii. Mention five differences between mitosis and meiosis.

Conclusion: Teacher ends lesson by reinforcing students accordingly and giving them notes to copy.