UNIVERSITY OF EDUCATION, WINNEBA

USING MULTIMODAL INSTRUCTIONAL APPROACH TO IMPROVE SECOND YEAR SCINCE STUDENTS' CONCEPTUAL UNDERSTANDING AND KNOWLEDGE RETENTION OF PHOTOSYNTHESIS AND MINERAL NUTRITION

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MASTER OF PHILOSOPHY

2021

UNIVERSITY OF EDUCATION, WINNEBA

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**A thesis in the Department of Science Education,
Faculty of Science Education, submitted to the School of
Graduate Studies in partial fulfilment of
the requirements for the award of the degree of
Master of Philosophy
(Science Education)
in the University of Education, Winneba**

OCTOBER, 2021

DECLARATION

Student's Declaration

I, Tetteh, Abel Kodjo, declare that this thesis, with the exception of quotations and references contained in published works which have been identified and duly acknowledged, is entirely my own original work, and that it has not been submitted, either in part or whole, for another degree elsewhere.

Candidate"s Name: TETTEH, ABEL KODJO

Candidate"s Signature: ……………………………………

Date: ……………………………………………

Supervisor's Declaration

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines on supervision of thesis as laid down by the University of Education, Winneba.

Supervisor"s Name: DR. JAMES AWUNI AZURE

Supervisor"s Signature: ………………………………………

Date: ………………………………………………..

DEDICATION

I wholeheartedly dedicate this work to my children - Anita Amanorki Tetteh and Paul Amanortey Tetteh.

ACKNOWLEDGEMENTS

I wish to express my heartfelt gratitude and much appreciation to God Almighty for the guidance, protection, strength, knowledge, wisdom, mercy, provision and direction, given me, His servant, to successfully complete this research work.

My sincerest thanks go to my supervisor, DR. JAMES AWUNI AZURE, a lecturer in the Department of Science Education, University of Education, Winneba, who whole-heartedly offered constructive suggestions and directions to the conclusive end of this research study.

Also, to all my siblings – Daniel, Cephas, Samuel, Rebecca and Tabitha – for their prayers, moral love and support.

Great thanks to my nephew, Agabus Tetteh Patu, for your guidance, assistance, advise and encouragement in the course of writing this thesis, not forgetting Vera Mamle Sebbie for much support offered me.

Lastly, to all my respondents of 2020 year batch from 2 Sc 1 and 2 H 2 of Nifa SHS who contributed in no small way for this study to land on a fertile soil.

God bless you all.

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ABSTRACT

This quasi-experimental research study is aimed at improving students" conceptual understanding and knowledge retention in Photosynthesis and Mineral Nutrition in plants using Multimodal Instructional Approach, MIA in Nifa Senior High School. The research also investigated learners" perceptions of using MIA in teaching and learning. Fifty second year science students of the school were selected as participants for this study using stratified random sampling technique. The sample size consisted of 24 male and 26 female students. They were assigned into two groups of experimental and control of 25 students per group. The implementation of the intervention lasted five weeks with three 2-hour lessons per week. Research participants in the control group were required to re-examine the lesson making use of question-answer approach and allocation of tasks in the textbook as pieces of assignments. On the other hand, MIA in the forms of educational videos, scientific games and practical activities were used to guide and facilitate the review, reinforcement, motivate and assessment of participants in the experimental group"s lesson materials. Student t-test was used to analysed quantitative data collected whereas descriptive statistic was used to analysed qualitative data. Analysis of Conceptual Understanding Test and Knowledge Retention Test shows a p-value of 0.0007 and 0.009 respectively. These values revealed a statistically significant difference in respondents" conceptual understand and knowledge retention in favour of the experimental group. Again, there was no statistically significant difference in respondents" conceptual understanding ascribed to gender variable, p-value = 0.42. The results suggested that MIA promoted students" conceptual understanding and was an effective tool in facilitating the retention of new information. Within the context of the research, the perceptions of the experimental group respondents on the use of MIA were established at the end of the intervention period. These views were, in general, positive. The study found the use of MIA to be effective method of reinforcing learning, increasing and sustaining students interest in learning and also provided excellent motivation for learning. The research recommended the use of MIA in teaching Biology and other science subjects in Nifa Senior High School.

CHAPTER ONE

INTRODUCTION

1.0 Overview

Chapter one provides an introduction and structure of this study and the various subheadings covered in conducting this research work. I also introduced the research problem addressed in this study, the purpose and significance of the study in relation to previous researches, and my specific research questions. Chapter one concludes with key terms as well as operational definitions that are used in the succeeding chapters.

1.1 Background to the Study

Students in a classroom setting are, to a large extent, not the same. Each has a unique as well as complex "dimension" of understanding and learning concepts. We cannot therefore just assume that they should be taught the same way. As professional teachers, it is incumbent upon us to know and design better ways of instructing our students. Possibly, approaches to the best solutions might be found by integrating various instructional modes available and more relevant instead of just a one-way approach. Multimodal Instructional Approach (MIA) such as the use of videos, games, practical activities, computer simulations, online classroom mode and three-dimensional objects are such modes that its effective application will not only result in healthy learning opportunities to students, but also is more likely to make it possible for holistic assessment and interpretation of students learning progress.

In our contemporary world it is very necessary to grab the advantage of the Information and Communication Technologies to assist creative methodologies of teaching Biology in the Senior High Schools.

The multimodal instructional techniques are formed from the combination of the abstract methods like language, symbols, image, sound etc. These methodologies broaden the cognitive domain when they are combined by the sensory modalities together with their visual, tactile, olfactory, auditory and kinaesthetic features. These, in general, are referred to as semiotic resources. In this manner, understanding concepts in Biology classroom is effective via the articulated use of various semiotic modes (Kress, Ogborn & Martins, 1998).

Also, meaning making and knowledge construction in science occur through effective and efficient interaction between the learner"s knowledge schemes and his or her excellent experience with the environment. As the usage of media by students on regular basis increases astronomically, the learning environment of the school seems different compare to the various technological learning conditions the student is exposed to outside the school.

Analyzing a study in education on multimodality, Jewitt (2008) states that "the contemporary conditions of the communication and digital technologies create the movement of images and ideas across geographical and social spaces in ways that affect how young people learn and interact"". Jewitt"s pronouncement has indications on how students learn as they go through formal educational system and teachers who need to have students" attention, engagement and finally motivation in the classroom setting as a result of these diversified learning opportunities.

A recently conducted survey indicates that there is an increase in the usage of technology by students for educational or learning purposes. The research cited the use of cell phones by students of third to twelfth stage and result revealed that 20% of third stage learners possess cell phone, out of which 90% of users are active online, whereas 83% of learners in middle school have and use cell phones (Englander, 2011).

Kress (2003) maintains that the transformation of learning science is changing, not only from the centuries old method of writing to the new method of image, but also the movement from book to that of the screen for a learning medium which serves holistically to make a revolution in representation and communication at each level of the educational system.

From the historical view point of education, attempts were made to incorporate various technologies into the classroom. Presentation of information and concepts to learners in schools differs widely on the basis of individual teacher‟s abilities and capabilities, and to a large extent the availability of technological means.

Technically, the means comprise the channels through which multimodal successes are realized such as printed texts, phenomenon scheme written in a chalk on a chalkboard, holding of an event, television, computer, photo camera, movie camera, data show or any other material object (Arroio, 2011; Dicks et al, 2006; O‟Halloran, 2008; O‟Halloran, 2011).

Lemke (1992, 1998), maintains that the appropriate organisation of meanings in Natural Science classroom is not just produced through the vocabularies that are said, but also by the diagrams and charts that are drawn and the formulae that are written down, and the experiments that are carried out by students and teachers using the various technological means available to the school. Jewitt (2002) again explains that "how knowledge is presented, as well as the mode and the media chosen, is a critical aspect of knowledge construction, making the form of representation integral to meaning and learning".

The common technical terms associated with biology and experimental procedures require MIA for spirited presentation of the subject matter in meeting the needs of the learners. The difficulties in assimilating fundamental concepts could be as a consequence of using just a single mode of instruction rather than MIA. The relevance of using MIA as a method of imparting knowledge in science education is that it allows learners to be fully and actively involved in the teaching and learning process, and at the same time gain the talent to advance an intuitive knowledge in fundamental conceptualization in a visual assessment environment (Muraina, Adegboye, Adegoke & Ologido, 2019). Thus, learners engaging with practical modes as the science educator make an excellent move to inculcate in learners the ability to conduct actions privately.

Julinar argued in her researcher study that teachers expressed their perception about multimodal approach as an excellent method that resulted in their effectiveness in teaching. She stated that 65% of the teachers interviewed expressed their satisfaction with the multimodal approach in that it was effective and useful in assisting them to present lessons to the students. Also, the study found multimodal videos as guides that promoted students understanding in learning new concepts. The study stated that the teachers created new materials articulating various modes of communication that give a variety of sources of input to the subject unit under study via multiplicity of activities.

It is against this background that this research work is intended to be carried out as a tool to help improve students" conceptual understanding and knowledge retention of Photosynthesis and Mineral Nutrition in Nifa Senior High School.

1.2 Statement of the Problem

Most science students more often than not encounter difficulties in understanding biological concepts (Selvi & Çoşan, 2018). For instance, many students tend to rote memorisation of complex terminologies to comprehend the topic, which fundamentally distract their attention from the lesson (Gutierrez, 2014).

Science students of Nifa Senior High School are no exception to the above stated difficulty. They often encounter challenges in learning photosynthesis and mineral nutrition topic in the elective biology syllabus. This is as a result of the complexity of the topic, typically in the manner the subject is delivered to the students that lacks arousing and sustaining interest of students which is a typical characteristic of conventional methods of lesson delivery. Because of this most students could not make the required grade of A1 to C6, which is the basic requirement for admission into higher institution of learning as argued by Ajayi (2006) that educational performance is the marker for successful college and university enrolment, scholarship awards and future job success.

It was also noted from the annual WASSCE results analysis of the school that about 40% or more of the candidates score the „„faled grades""of D7 to F9, as indicated in Table 1, and therefore cannot be admitted into higher institutions of learning. This is not acceptable. According to Ameyaw-Akumfi and Enstua-Mensah (2004), any programme of science education that fails more than 40% of its candidates should be re-looked at; because no nation can develop its science and technology base efficiently and effectively if more than 40% of students fail to comprehend basic concepts and terminologies in the subject.

The West Africa Examinations Council (WAEC), for instance, in 2016, summarised students" weaknesses in biology as outlined below:

i. Failure of candidates to adhere to the convention of writing scientific names;
ii. Failure of candidates to relate the theory they have learnt to practical work;
iii. Use of the plural forms of label to a drawing when the guideline points to a single structure;
iv. Technical terms were wrongly spelt by many candidates. Technical name of species of organism started with small letter; and
v. The size of the vacuole was not large and centrally positioned than that of the nucleus.

Therefore, this research work seeks to investigate how best the use of Multimodal Instructional Approaches (MIA) could be used to improve science students of Nifa SHS conceptual understanding of photosynthesis and mineral nutrition in plants as well as the perceptions of learners on the use of MIA in teaching and learning of biology.

Table 1: Nifa SHS Candidates Performance in the May/June 2020 and 2021 WASSCE Biology

Year	No. of Candidates	A1	B2	B3	C4	C5	C6	D7	E8	F9	% Fail (D7 – F9)
2020	160	0	01	24	14	20	45	35	12	09	35.00%
2021	160	01	0	07	05	03	27	29	31	57	73.13%

Source: Statistics unit of Nifa SHS

1.3 Purpose of the Study

Many educationists and researchers such as Kress and Van Leeuwen (2001), Copa and Kalantzis (2009) recognize the importance of multimodality in lesson delivery. foremost purpose of conducting this research work is to improve students" conceptual understanding of Photosynthesis and Mineral Nutrition in Biology through the use of Multimodal Instructional Approaches (MIA) in Nifa Senior High School. The research will also investigate the perceptions of learners and teachers on the use of MIA in teaching and learning biology.

Downey (2008) writes that "teachers need to know how their daily work in classrooms can be infused with interactions and instructional strategies that research has shown can make a positive difference in the lives of students who are at risk of academic failure"

1.4 Objectives of the Study

The objectives of the study were to:

1. investigate any significant difference between the pre-tests of the control and experimental groups before the intervention using MIA.
2. investigate any significant difference between the post-tests and knowledge retention test of the control and experimental groups after exposing the experimental group to Multimodal Instructional Approach.
3. investigate any significant difference in the performance of male and female respondents taught using the Multimodal Instructional Approach.
4. investigate the perceptions of learners on the use of Multimodal Instructional Approach in teaching and learning of photosynthesis and mineral nutrition in Biology.

1.5 Research Questions

The underlisted research questions served as a guide to the study. To:

1. what extent is the pre-test of the control group significantly different from the pre-test of the experimental group before the intervention using MIA?
2. what extent is the post-test and Knowledge Retention Test of the experimental group significantly different from that of the control group after exposing the experimental group to MIA?
3. what extent is the performance of male students different from female students who were taught using the MIA?
4. what are the perceptions of learners and teachers on the use of MIA in teaching and learning photosynthesis and mineral nutrition?

1.6 Research Hypotheses

The research aims at testing the following null hypotheses at alpha (α) level of 0.05.

- H_{O1}: There is no statistically significant difference in the pre-test performance of control and experimental groups.
- H_{O2}: There is no statistically significant difference in the performance of students taught using MIA and those taught using traditional method in the post-test and Knowledge Retention Test.
- H_{O3}: There is no statistically significant difference in the performance of male and female students taught by using the MIA.

1.7 Significance of the Study

The study will be of much importance to the school management, teachers and students of Nifa Senior High School. Outcomes and recommendations of the study will be used by the teachers and students of the school to re-direct the teaching and learning of biology as well as other science subjects. This would subsequently lead to capacity building of in-service teachers of the school on the integration of Multimodal Instructional Approaches in teaching science subjects and the provision of appropriate and adequate multimodal equipment in the school. The research will also contribute immensely to knowledge by combining several instructional approaches for teaching and learning biology rather than considering just one or two approaches which may not embrace the various human senses involved in learning and skills development. This integration and employment of multiple modes in teaching and learning biology allows for creativity and flexibility in student-teacher interaction. The study will also serve as basis for further research.

1.8 Delimitation

This research study was conducted in only Nifa Senior High School in the Okere District because of proximity, time constrain, accessibility and covid-19 restrictions. Also, the study was restricted to only second year science students of the school. Another delimitation was that the intervention covered only photosynthesis and mineral nutrition unit of the entire Biology syllabus, and finally the research was limited to the use of Multimodal Instructional Approach as the methodology for teaching and learning the topic under consideration.

1.9 Limitations

Cohen, Manion and Morrison (2018) maintain that the main purpose of conducting experimental research has to do with objective measurement of treatment. They argue that this yields analytic generalizations about efficacy.

One limitation to this particular study was due to student absenteeism during the period of intervention. This may have a significant negative correlation to their performance in the post- test analysis. AIP (2018) revealed a negative correlation between students‟ absence from class with academic performance (r = -0.611). Another limitation to this study is the non-inclusion of perceptions and experiences of other sub-population of students such as first and third year biology students. Another limitation was that covid-19 restrictions affected the methodology of instruction such as group work due to social distance policy. Group work is normally carried out when materials for, especially, practical work is not enough to initiate individual work. Lastly, the results of this study cannot be applied to all schools because the sample selected and used was from only one school.

1.10 Operational Definition of Terms

Explication, formally, in research work, deals with the definition of term in order to avoid bias. Stake (2010) explain that clear definition of terms and operations provides not only the researcher clarity as some key concepts of the research study become explicit, but also the reader.

Below is the set of technical terms to be used in this study:

Multimodal Instructional Approach: This basically refers to the combination of different modes to deliver the same content to students. It is used interchangeably with multimodal instructional technique.

Science students: They are senior high students who offer biology as one of their elective subjects.

Scientific Games: These are games purposely designed to help science students learn a particular concept in science

Multimodality: The interplay between different representational modes

Professional teachers: They are elective biology teachers of Nifa SHS with at least five years of teaching experience with the relevant professional qualification of B.Ed. (Biology) or BSc (Biology) with Postgraduate Diploma in Education.

Mode: Simply refers to the kind of stimulus that is fed to the student to produce a response.

Media: They are tools and material resources that are used in the classroom to make and convey texts.

Failed Grades: These refer to WASSCE grades of D7 to F9 which a candidate cannot use for admission into tertiary institution of learning.

Multimedia: It describes texts composed by using a computer to combine words and visuals in addition to sound and video. In this study, it is used interchangeably with multimodal

1.11 Organisation of the Study

The first chapter of the study opens with an introductory section and overview of the structure of this research work. Research problem as addressed in this study was introduced. The chapter further discusses the purpose, limitations as well as the significance as related to past studies. The chapter again outlines the specific objectives, research questions and hypotheses to be tested. It finally ends with operational clarification of keys terms and variables that are used in the succeeding chapters.

Review of related literature relevant to other studies was discussed in chapter two of this research work. The review includes an historical background of multimodality in the classroom. It also discusses the relevance of videos, games, and practical activities to the effective teaching and learning of the topic under researched. The chapter will conclude with various views and arguments on the topic and suggested by different researchers.

Third chapter was on the research design employed in the study. The chapter starts with an overview and concludes with data analysis. Other areas covered under the chapter include, but not limited to, the population and sample sizes, data collection and methods, etc.

Chapter four entails the research findings of the study and how it was thoroughly analysed and discussed. The thesis concludes with chapter five which provides an insight of the summary of findings, conclusions drawn from the research as well as recommendations and suggestions for possible further research.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

Chapter two of this research work provides a review of related literature on the topic of multimodality – educational videos, practical activities and scientific games - and the effect it has on the teaching and learning environment. The perspectives of a variety of sub-headings were discussed from the objectives of biology education in SHS down to multimodal instructional approaches, then to current thinking on this topic.

2.1 The General Aims of Teaching Biology in SHS

The vision of the National Science, Technology and Innovation Policy is:

> "to migrate the country from the current low science-and technology-poor practices and worldview associated with a society of traditional-bound culture, to an **STI and knowledge-based society** functioning within an economy based on high levels of productivity in all the sectors of the economy namely agriculture, industry and services" (MESTI, 2017).

This view can become a reality if science education at the middle level – SHS where science students take a 3-year programme of study in Chemistry, Physics, Biology Mathematics and ICT- receives a boost in terms of funding, teaching and intervention, and research. In line with the above stated vision, The MOE through its agency of GES, in 2010, outlined the general aims of teaching Biology in SHS, some of which are listed as follows:

i. Develop scientific approach to solving personal and societal (environmental, economic and health) problems;
ii. Develop practical skills required to work with scientific equipment, biological materials and living things;
iii. Collect, analyze and interpret data; and also, present data graphically;
iv. Sustain their interest in studying Biology;
v. Be aware of the existence of interrelationships between Biology and other scientific disciplines;
vi. Develop a sense of curiosity, creativity and critical mind; and
vii. Provide a foundation for those who will develop a career in biological sciences.

Ghana happens to be the first independent sub-Saharan Africa country, but for South Africa, not only to commence a comprehensive search to promote science education but also its application in industrial and social development (Anamuah-Mensah, (1999). Promotion of science education in terms of the drivers of change – funding, teaching and intervention, and research – of which teaching and intervention is the focus of this study will lead to economic independence of mother Ghana.

2.2 The Teachers' Role in Learning Biology

The calibre of science educators is the bedrock of any science programme in our educational system for raising scientifically literate citizens. "No educational standard can rise above the quality of the teacher", according to The National Policy on Education (FNG, 1998). And truly, "what students learn is much affected by how they are taught" (NRC, 1996). Learners come to science lesson with some preparatory ideas, formed through their interaction with their environment. While it is expected from learners to possess some fundamental knowledge about a science topic before learning it formally in class, some of their knowledge may be misconceptions. These misconceptions may interfere with the way they should learn the correct concept. Misconceptions in children were traced to be ones held by teachers (Abimbola, 1986; Otuka, 1987) as well as those held by parents, resource materials, peers, and the media. Hence learners with such background cannot attain higher grades of performance without a good calibre of talented and self-distinguished dedicated professional teacher (Gbadamosi, 2013). Science educators have been cited to have a major impact on learners‟ academic accomplishment because they (science educators) are solely responsible for putting policies into action, following guidelines and procedures during interactions with their students (Afe, 2001).

A governmental enquiry review into Australian teacher education contends that a good calibre of teachers is receptive and kid-glove to the distinctive educational demand of each child (CoA, 1980). Further studies into the role of quality science educators in classroom instruction and processes reveal that quality educators exhibit commitment; display subject specific content knowledge and have a good working knowledge of their profession; love students; set good moral standards; control group productively; integrate new technologies in their instructions and students‟ learning; apply multimodality in the teaching and learning process; modify and extemporize their classroom practices; have in-depth knowledge of their students as individuals; exchange ideas with one another; perform reflective practices; cooperate with other instructors in promoting the teaching profession; and also, subscribe to the larger society (OECD, 1994; Shulman, 1986). Progressively, Abell and Pizzini (1992) states that the science educator‟s role includes being a mentor, a person who facilitates learners‟ deep comprehension, and also, one who promotes the acquisition of children‟s in-depth thinking and creativity in problems analysis and solving procedures.

Fundamentally, high quality of science educators are described as "facilitators, mentors, constructors, open-minded, independent professionals, active cooperators and collaborators, mediators between learners and what they need to know, providers of scaffolding for understanding, coaches and creators of learning environment and also have a rich understanding of the subject(s) they teach and appreciate how knowledge in their subject relates to other disciplines in helping learners to acquire knowledge" (ACSA, 2000).

Consequently, distinguished science educators are teachers who engross learners in higher cognitive skills, facilitate information literacy, advance collaborative and cooperative classroom practices among learners or indirectly shape the learner‟s attitude towards science, which accordingly affects students‟ academic achievement.

2.3 Constructivist Approach

Constructivism is one of the theories of learning which is generally accepted nowadays as a result of its functionality in harbouring a vast range of observations, individual learning and problem-solving behavior (Mestre, 2001) and yield new understanding into classroom teaching and learning, positioning students at the „median‟ of their own learning (Haydey, 2005). Proponents to this learning approach see the classroom as a "mini-society, a community of learners engaged in activity, discourse, interpretation, manipulation, justification and reflection" (Fosnot, 2005). The constructivist approach, which derived its root in the ideas of Jean Piaget explain that knowledge is actively constructed by individual student, and as such the learning takes place in a well-structured environment with adequate experiences properly assembled and administered by the teacher. The "effective implementation of learning theories in higher education has an impact on student"s performance" (Zirawag, Olusanya and Maduku, 2017). Ben-Ari (1998) maintains that constructivist applications in science education reinforce motivation of learners to search information without any input from the educator when administered in favourable conditions. Bi (2013) stated that students construct new knowledge from their engagement through the methods of settlement and osmosis. Osmosis is the method of merging new experiences into current schema whereas settlement adapts to accommodate new experiences.

The Constructivists maintain that teaching is not transferring knowledge from the teacher to the learner's brain. Teaching is more concern of an activity and interaction that helps learners build knowledge. The role of the science educator is not to transfer the knowledge he has to students, but more as a mediator and facilitator who helps learners to construct their knowledge quickly and effectively. For that purpose, science educator must be:

a. creating a conducive constructivist learning environment that supports effective knowledge construction by the students;
b. exploring the initial knowledge of learners because the knowledge that students already have may interfere with their ability to construct new knowledge. If the new knowledge they try to construct disagrees with the formerly constructed knowledge, the latter knowledge will not make meaning and its construction may not be useful for long-term recall and not of

application in a different circumstance (Anderson, 1987; Glasersfeld, 1989, 1992; Resnick, 1983, 1987). Mestre (2001) expresses similar view when he said:

> Constructivism has important ramifications for learning and instruction. In the constructivist view, the learner‟s mind is not a blank slate upon which new knowledge can be inscribed. Knowledge previously constructed by the learner will affect how he or she interprets the knowledge that the teacher is attempting to impart. In short, learners are not sponges ready to absorb the knowledge transmitted by the teacher in ready-to-use form. From the perspective of instruction, a constructivist teacher needs to probe the knowledge that learners have previously constructed and evaluate whether this knowledge conflicts with the knowledge being taught. If it does, the teacher must take care to guide learners in reconstructing knowledge; otherwise, there is no guarantee that learners will accommodate the new knowledge in a way that is compatible with current scientific thought. To ignore learners‟ pre-knowledge makes it highly probable that the message intended by the teacher will not be the message received by the student.

c. making use of learning strategies that enable learners construct the knowledge independently. The idea of multimodality – use of videos, practical and games – fits directly into the constructivist theory of learning. A quote by Johan Huizinga "Let my playing be my learning and my learning be my playing" confirms learning and hands-on activities should not be seen independently for learning to be effective it should be structured in the same manner learners embrace having fun (Roblyer & Doering, 2013). Guided discovery is another strategy identified as effective means of promoting constructivist learning (Mayer, 2004). The term guided discovery generally points to a teaching and learning process in which students are actively involved in discovering knowledge. The pedagogical reinforcing is that if the learners discover the knowledge, they will, going forward, have constructed a new knowledge. "This construction of knowledge is a life-long, effortful process requiring significant mental engagement by the learner" (Mestre, 2001) as the science educator acts as facilitator, making available all the resources and materials needed by the students to interact with; and

d. creating service teacher-learner interaction and learner-learner interaction as postulated by John Dewey‟s Social Activist Theory (1859–1952) that leaners should be experienced through a combination of different interactive activities as their method of learning is geared towards hands-on (Conner, 2011).

Current information arising out of the ideas of cognitive science put forward that students learn through continuous construction and reconstruction of knowledge experience (Gablinske, 2014), and that extensive conceptual learning rotates around constructional switches in cognition; without reciprocity with the environment, entropy will result (Fosnot, 2005). And so, knowledge is rigorously constructed in an extensive principle of constructivist thinking (Gablinske, ibid). In constructivist theory, knowledge is perceived as an exercise of construction in lieu of dissemination, as the instructor assists student learning, making use of co-operative groups to thrash out meaning (Haydey, 2005).

In perceiving the science educator‟s role as the promulgator of knowledge, constructivists approach rather concentrates on the expertise and the multifaceted opinions of both the instructor and the students as they construct knowledge together, assisted by multimodal text and multiple and various media (Au, 1998). Glasersfeld (1987) states that knowledge cannot just be transferred and that „compelling‟ is not the most effective method of instruction. Constructivists, however, believe that knowledge acquisition demands the active and full participation of learners with the teacher providing the necessary scaffolding.

Constructivism provides a general and best plan for this research because the mode of teachers‟ instruction is thus influenced by our comprehension of the learning process that has theoretically metamorphosized from a behaviorists approach to a cognitivist theory to a constructivist stance Jetton & Alexander, 1998).

2.3.1 Multimodality: An Introduction

The concept of multimodality evolved and developed in the 1990s. The concept refers to the use of different modes to present the same information to students. The term was finally coined by educationists and researchers such as Kress (2003, 2000), Cope and Kalantzis (2009), Kress and Van Leeuwen (2001). These scholars contend that currently, communication is not limited to only a single mode such as text carried through one medium such as a book. Instead, as a result of digitalization, all modes can be presented through a single binary code and that the medium of the screen is becoming the major site where many modes can be composed to make meaning in dynamic ways.

Kress and Van Leeuwen (2001) argued that the operation of all modes can be carried out by just one multi-skilled person, by the use of an interface, one mode of physical control in order to show ideas with sound or music, visually or verbally. The authors further revealed that multimodal information is characterized by combination of ideas assembled together through the integration of modes such as images, texts, colour etc.

Multimodality connects to different tools and resources as channel of communication in order to make a meaning. It is a term used not only to describe a way of human communication, but also to name the various diversified and growing field of research (Adami, 2015). She further explained that as a system of communication, multimodality defines the integration of various semiotic tools or modes in communicative programmes. In terms of inquiry field, multimodality research deals with development of theories, analytical machinery and in-depth descriptions that deals with the examination of representation and communication, giving attention to modes as guiding principle.

Jewitt (2009) is of the view that the success of multimodality is practiced through diversified theoretical views. "Multimodality as a field of research conceives of representation and communication as relying on a multiplicity of modes, all of which have been socially developed as resources to make meaning" (Adami, 2015).

2.3.2 The Historical Context of Multimodality

The occurrence of multimodality, in the history of writing, has experienced escalating theoretical characterization. Arguably, since the 4th century BC, the occurrence has been under study, when prime rhetoricians verbinitiate to it with their accentuation on voice, gesture and expression in public speaking. Nevertheless, the concept was not entirely expounded with significance till the 20th century. During this period, an augmented rise in technology produced many new modes of demonstration. Since that time, multimodality is viewed as standard in the 21st century, pertaining to different network-based conformations, including advertising, social media, art etc. Bateman (2008), in his book, *Multimodality and Genre*, contends that "Nowadays text is just one strand in a complex presentational form that seamlessly incorporates visual aspect „around", and sometime even instead of the text itself".

Kress and van Leeuwen (1996), in their landmark book *Reading Images,* made changes to an earlier work by Halliday (1978) which uses the three metafunctions –

ideational, interpersonal and textual – to describe meaning produced by pictures and their integrated utilization in writing. Earlier, O‟Toole (1994) used the metafunctions to analyze visual art. Van Leeuwen (1999) represented the metafunctions onto speech resources, music and sound.

2.4 Multimodal Instructional Approaches (MIAs)

MIAs, according to Muraina, Adegboye, Adegoke & Ologido (2019), are tools used in the classroom to help the brains of learners function better in accordance to the instructional information upon which they are expected to work.

Multimodality in the 21st century has caused educational institutions to consider changing the form of its traditional aspects of classroom education. With a rise in digital and internet literacy, new modes of communication are needed in the classroom in addition to the print, from visual texts to digital e-books. Rather than replacing traditional literacy values, multimodality augments and increases literacy for educational communities by introducing new forms of classroom instruction. Miller and Mcvee (2013), authors of *Multimodal Composing in Classroom,* argue that „„„These new literacies do not set aside traditional literacies‟‟‟. Students still need to know how to read, write, calculate, perform experiments and apply what they learnt in solving daily problems. The learning outcomes of the classroom stay the same, including – but not limited to – reading, writing and language skills. However, these learning outcomes are being presented in new forms as multimodality in the classroom which suggests a shift from traditional media such as paper-based text to more modern media such as screen-based texts. The choice to integrate multimodal forms in the classroom is still controversial within educational communities. The idea of learning has changed over the years and now, some argue must conform to personal and affective needs of new students. In order for classroom communities to be legitimately multimodal, all members of the communities must share expectations about what can be done through integration, requiring a shift in many educators" thinking about what constitute effective teaching and learning in a world no longer bound by print text.

It is very necessary to notice that all facets of classroom instruction provide students with perceived forms of stimuli - audio, visual and somatosensory- while at the same time students" own reminiscence and intrinsic cause total internal distractions. In order to guide students to respond to new information or stimulus, it is healthy to organize a variety of modes at specific times during the course of instruction or assignment. Muraina, Adegboye, Adegoke and Ologido (2019) mentioned that „„each mode allows the student to connect any given concept to a different aspect of sensory memory"". Videos, scientific games, audios, practical etc are all forms of MIAs.

2.4.1 Videos

2.4.1.1 Introducing Educational Videos

The study of filmstrips as a coaching kit for soldiers during the period of World War II enlightened educators the importance of audio-visual tools to capture and sustain the interest and attention of students, escalate their motivation while at the same time intensifying their learning exploits (Hovland, Lumsdaine & Sheffield, 1949). The authors maintain that not only the technology and the content saw a massive development during that period, but also a corresponding increase in the availability and usage of audio-visual kits in the classrooms. Content development started with Instructional Television (ITV) in the 1950s, of which taped lectures can be replayed. This continued with the advancement of Educational Television (ETV), with the aim of complementing classroom teaching and learning process, rather than being a competitor (Corporation for Public Broadcasting, 2004) to quality-based instructional videos mainly designed for augmenting classroom tools. Instructional technologies saw a significant advancement from simple filmstrips to Cable Television (CTV) and finally to the conformability of Video Cassette Recorders (VCRs) as well as Digital Versatile Discs (DVDs). Lastly, the emergence of digital technology influenced the field of education, making it the state-of-the-art with a larger potential of flexibility in teaching (Cruse, 2007).

The utilization of instructional videos in schools has increased immovably over the last three decades, according to a number of researches carried out by CPB. These studies take into account not only the pattern of usage, but also the attitudes of the teacher as well as his expectations for outcomes. According to current studies, educational videos and television were used widely and exceedingly valued as a method of teaching productively and innovatively (CPB, 1997).

Cruse (2007) explains that „„„among frequent users – teachers who report using TV and video for two or more hours per week – two-thirds find that students learn more when TV or video is used, and close to 70% find that student motivation increases. More than half of frequent users also find that students use new terminologies as a result of video use"".

A report of recent study and educator survey by CPB (2004) indicates that video and television for classroom instruction enhances:

i. Reading and lecture resources
ii. Development of a common base of knowledge among learners

iii. Learner understanding and discussion

iv. Accommodation of different learnings

v. Learner motivation and enthusiasm

vi. Teacher creativeness and effectiveness (CPB, 2004).

2.4.1.2 Learning through Educational Video

Current studies support the theoretical idea that learning through video is a vital process, which can be „„„an ongoing and highly interconnected process of monitoring and comprehending"" and „„„a complex, cognitive activity that develops and matures with child"s development to promote learning"" (Marshall, 2002 as cited in Cruse, 2007).

According to Mayer (2001), while viewing may be considered secondary, it can, at the same time, be an effective tool for excellent intellectual activity required for active learning. He contends that „„„well-structured multimodal instructional information can elevate active intellectual processing in learners, even when they (learners) appear inactive. Both the content and the framework of viewing are critical ingredients for involving the class as active students. CPB (2004) explains that content must correspond to the age and skill level of students as the content the learner views will be a dominant determinant of his future academic attainment rather than the number of times, he spends viewing and listening to TV. Some areas of video discussed with have involved participants in active studies are its ability to solve different arrangements of intelligence, its multimodal usage for content delivery and lastly its psychological interest to viewers (Cruse, 2007).

2.4.1.3 Numerous Intelligences

Intrapersonal, logical-mathematical, spatial, bodily kinesthetic, linguistic, musical, interpersonal and naturalistic are identified by Gardner (2006) as multiple intelligences that any individual possesses in an even degree of strength and preferences. Marshall (2002) argues that the comparative strengths and weaknesses connecting these variables (intellects) speak the mechanisms in which a learner processes information, view the world and learn. Marshall"s theory shows a great deviation from the viewpoint of traditional intelligence, which acknowledges verbal and mathematical ability only (Brualdi, 1996).

The postulation by Gardner implies that the way in which content is presented will impart that student"s ability to study, and that science educators need to consider these intellects when organizing lessons (Brualdi, 1996). As textbooks frequently go with linguistic way of learning, video"s numerous modes, however, can admit a wide range of methods, including logical plus linguistic as a way of solving the various learning challenges of students. „„,These „multiple entry points" into the content are especially valuable in a formal education setting, as they offer greater accommodation to the multiple intelligences of a diverse group of students""(CPB, 2004).

2.4.1.4 Multimodal Learning Techniques

According to Miller (2001) and Pruitt (2005), three forms of learning techniques – aptitude-based, personality-based and sensory-based – are widely accepted. The authors explained that the first (aptitude-based) extracts on Gardner"s postulate of multiple intelligences, the second (personality-based) is measured by Meyers-Briggs test and the last (sensory-based) takes into consideration the modalities by which learners grab in information. These originations of learning techniques seek to illustrate the need to broaden the direction of learning beyond just one mode of direction.

Visual, tactile and auditory have been identified as the three predominant methods through which information is taken in by people. These three methods were linked to how learners process information (Silverman, 2006), deriving three fundamental learning techniques namely auditory-sequential, visual-spatial and tactile-kinesthetic. Auditory-sequential students contemplate in words, recycle information auditorally and broadly study in a sequential manner. Visual-spatial students assimilate new materials through mental pictures of the entire concept and think holistically. On the other hand, students who learn through tactile-kinesthetic way absorb new its material through physical contact and sensation (Cruse, 2007). This category of learners derive benefit from demonstrations rather than word-to-word explanation.

According to CPB (1997), the importance of video, with content mainly channeled visually, for visually-aligned students is apparent immediately. „„„Videos also benefit auditory learners, with inclusion of sound and speech, and can provide demonstrations not otherwise possible in classrooms for tactile learners"" (Cruse, ibid).

2.4.1.5 Binary Learning System

Truly, all categories of learners benefit, massively, from teaching that involves video. From Dale"s Cone of Experience, Wiman and Meierhenry (1969) conclude that: „„people will generally remember:

10% of what they read

20% of what they hear

30% of what they see

50% of what they hear and see"""(pp. 7-8).

In support to this, Computer Technology Research, CTR reports that students retain as much as 80% of what they see, hear and do simultaneously (Timothy, 1998).

As a type of multimedia, video transports information simultaneously through two sensory mechanisms, viz visual and aural. Video frequently makes use of different presentation modes, including verbal and graphic presentations subject to televisual print and closed-captioning (Mayer, 2001). This variety illustrates that video transmits the same content to students through concurrent learning techniques and can supply learners with „„multiple point of entry"""into the subject matter according to Gardner (2006).

Gardner (2006) says that „„to promote awareness of the interrelationship between modes (pictures, movement, sound etc)""" video can be used. Kozma (1991) reveals that a blend of verbal language, still pictures and text in TV and video ends in grater learning outcomes compare to media that depend fundamentally on just a single of these channels. CPB (2004) cited in Cruse (2007) concludes that the combination of sound with either still or movable pictures aggregates than just combining motion to still pictures.

2.4.1.6 Research Basis for using Video in the Classroom

During the time of NCLB, any new programme in the educational sector must yield a positive increase in student achievement as gauged by standardized, empirical research. Tv has been assessed for more than fifty years for its importance to education and a host of studies show that TV and video are excellent instructional tools in the classroom, with positive results in academic as well as affective learning

(Cruse, 2007). A research study conducted by Corporation for Public Broadcasting in 2004 gathered that „„children‟s viewing of educational television has been shown to support significant and lasting learning gains"" and that „„a positive relationship has been found between childhood viewing of educational television and cognitive performance at both preschooler and college levels"".

2.4.1.7 Growth of Early Literacy

A great deal of research has been carried out on the topic „„the impact of educational television and video on young children and their literacy skills"". Cruse (2007) explains that causal correlation between children who view *Sesame Street* (the most widely studied educational television programme) and their academic and intellectual development has been archived for over third years. Researchers conducted from the early 1970s has been summarized by Fisch (2003) which gives robust evidence for the „„educational effectiveness of *Sesame Street*"". Among early grade students, habitual *Sesame Street* viewers exhibited remarkably substantial growth in a diversity of academic prowess and in school preparedness. These results have lasting positive benefits for learners, as demonstrated by a „„recollect""research that establish learners of high school who viewed Sasame Street and some other educational television and video as early grade students had better grades and manifested excellent pedagogy of self-esteem than peers who did not viewed instructional TV (Anderson 1987, cited in Cruse, 2007).

Linebarger (2000) explains that research on the impact of the early literacy project *Between the Lions* reveals that students of KG who viewed the programme not only performed creditably than their colleagues on specific programme subject matter, but also were able to apply this subject matter gained to illustrate remarkably improvement in growth in fundamental early literacy ability and universal reading ability. A conclusion drawn from a recent study by Prince, Grace, Linebarger, Atkinson and Huffman (2002) shows that programme viewing, coupled with classroom support and at-home projects aided poverty-stricken students, students in rural areas and students" speakers of ESL outstandingly outperformed control groups on various crucial reading prowess.

2.4.1.8 Further Researches

A repertoire of researches has reinforced the use of TV and video with mature students in a different content area. Notably among these studies are:

i. Two different researches by Barron (1989) dealing with using video to „„hold""direction to a common classroom encounter indicates an improvement in the use of vocabulary, better comprehension of scheme and characterization and extension in ability to make judgement gleaned from historical information.

ii. Rockman"s (1996) study theoretical impact of home and school watching of *Bill Nye the Science Guy* indicated that learners who viewed the entire programme were better able to outline more perfect and multiple clarification of scientific theories. Besides, the knowledge gaps between the male and female and majority and minority groups of students were insignificantly and near equivalence after watching the programme.

iii. Six weeks long research by Barron (1997) indicates that using educational TV and video with 8th graders, learners in the class with TV programming performed creditably compare to control groups in test results, writing assignments, projects, problem-solving abilities and in their involvement in class deliberations.

iv. Fisch (2003) concludes that a research on the impact of *Cyberchase* on students" analytical skills put viewers ahead of nonviewers in analyzing problems and generated extra advanced solutions.

2.4.1.9 Addressing the needs of Peculiar Populations using Video

The use of video is a productive instructional apparatus for all learners, but its positive outcome on particular populations of learners is certainly promoting much attention always. A survey conducted by CPB (1997) argues that videos are ,,,,highly valued as teaching tools"" and ,,,,seen as especially effective for reaching visual learners and special populations"". Cruse (2007) explains that majority of teachers polled recount video and TV as ,,,,very effective""for educating learners with learning impairments.

Barron (1989) is of the view that apart from video creating learning environment that may not otherwise be available, it can also, in certain circumstances, provide a powerful learning avenue than a field trip in the sense that video can be ,,,,replayed and reviewed""as many times as possible to guarantee effective schooling by learners with learning disorders or those ,,,,students at high risk"" for substandard school performance.

A blended instruction of video and text yield an abundant source of information, giving a chance to identify sensory representation, topical issues and dynamic characteristics. Additionally, video provides students with scientific potential to discern positive moving events and to rapidly organize concrete mental models of events. Also, video permits learners to develop recognition skills which are in consonance to visual and auditory signals alternative to incidents labeled by the instructor. In conclusion, videos are beneficial for designing routine experiences for both the teacher and the student that will serve as a tool for facilitating new scientific knowledge.

2.4.1.10 How best to use Video in the Classroom

The utilization of TV and video as instructional device has increased tremendously over the last three decades. „„As the technology continues to grow both more sophisticated and more user-friendly, teachers continue to become more adept at integrating these media into their instruction"" (Cruse, 2007). Over a time frame of twenty years, the CPB conducted a study on using TV and video in the classroom. The result shows an increment in the use of and self-satisfaction with TV and video in the classroom setting. In one of the most current studies, 92% of respondents (teachers) argued that the use of TV and video aided them to instruct more effectively and efficiently while 88% contended that „„it enabled them to be more creative"" in the teaching field (CPB, 1997). The real usefulness of video depends greatly on how it is administered in the classroom. Meta-analysis and examinations of findings of research reveals that positive learning outcomes are significantly boosted and expanded when the video is blended into the rest of the teaching and learning process (Mares, 1996; CPB, 2004). Successful integration of video into effective teaching and learning process, according to Reeves (2001), involves adequate preparation and variety of activities before, during and after watching.

2.4.1.11 Motives and Expectations for viewing Video

Preparing to use video in the classroom starts with the teacher previewing the content, setting clear purposes for watching and looking for various features and information that will aid and support that purpose.

According to CPB (2004), the value of a video „„is highly correlated to its integration with the curriculum – how closely the content fits into the overall instructional sequence"". For example, microvideos – short instructional videos that focus on teaching a single, narrow concept – may be incorporated at the start of a unit to arouse curiosity or interest, during a lesson to usher demonstrations and meaning into the lesson that might not otherwise be possible. Assisting leaners to grip with videos as functional students requires the creations of the right environment for that learning purpose to take place (Cruse, 2007).

A revelation by Hobbs (2006) indicates that video and film are frequently used for purposes of non-optimal, in addition to filling time, quieting students, as a relaxing time from learning or as a winning bonus for good deeds. The edutainment function of videos fortifies the inactive watching and unquestioning admissible of acquire information that partners growing up in a video environment (Paris, 1997).

Outlining clear expectations for learners and giving a condition for the task, advantageous with any learning activities, may present a major opportunity for watching of video with core point that is hugely emotionally-charged. However, there is a „„sustained"" fears that in the absence of proper instructional directive and guidance, video may position students to be insensitive to or experience „„without help"" in the process of events being viewed.

2.4.2. Practical Work

2.4.2.1 Introducing Science Practical

Science practical work is a fundamental dexterity that every science student is expected to acquire before completing senior high school in order to enable him/her solve simple daily life-challenging problems and as a factor for good performance in examinations. On this premise, the Ministry of Education (2010) outlines the rationale for teaching Biology as to „„„equips the learner for further studies and research in pure and applied science and technology and guides the learner and makes him/her capable of critical thinking, making meaningful decisions and solving problems"". To achieve this rationale, The MOE allocated 3 periods of 45 minutes per week for practical work in Biology and emphasized that „„„the teaching of Biology should be student-centered and activity-oriented"". Therefore, practical work is seen as the pivot around which student"s performance rotates. Milar (2004) defined practical work to refer to „„„any teaching and learning activity which at some point involves the students in observing or manipulating the objects and materials they are studying"" (p. 2).

The „writings" detailing science practical activity indicate that science laboratories to be used to perform scientific research have been in existence around 17th century. Nonetheless, Jenkins (1998) explains that well-constructed and well-equipped laboratories for performing science practical came into existence in the 19th century. The beginning of the 20th century saw an improvement in the supply and delivery of laboratory apparatus and materials appropriate for teaching science practical in schools (Ghartey-Ampiah, Tufuor & Gadzekpo, 2004). During the Post-Sputnik period in 1957, the science curricular of America and England proliferates to other parts of the globe including Ghana. According to Jenkins (ibid) some concrete steps were taken which gave birth to comprehensive curriculum reforms in parts of Great Britain in the 1960s which was sponsored by the Nuffield Foundation. A second wave of curriculum development in science started in Wales and England in the late 1960s. According to Jenkins, and by the terms of the Nuffield Project, the objective of this reform is to engage students in practical laboratory work, which consequently will help students gain much experience in scientific inquiry. This initiative reinforces an earlier argument that all science lessons should be laboratory-oriented according to Ghartey-Ampiah, Tufuor & Gadzekpo (ibid).

Mintzes and Wandersee (1998) reveal that in the US, a committee of ten membership was tasked to develop a curriculum which places much emphasis on field trips and practical activities in the 19^{th} century. The development of this curriculum was rooted on the understanding that students study science by verification and application of ideas in the laboratory (Lunetta, Hofstein & Clough, 2004). This period witnesses the creation of a common scientific technique to conform to the positivistic course, which sees scientific knowledge as incontrovertible truth (Kraus, 2005) while at the same time students channeled a path of „laboratory recipe" to authenticate a science accuracy as outlined by Lunetta.

Scientific research and content knowledge were itemized Post-Sputnik period. During that same era „„philosophers questioned the positivistic view of science, and developers looked to the works of psychologists Piaget, Brunner and Schwap for a rationale for science curriculum"" (Kay, 2014). Such perspectives on science education peaked up in a framework that supports the development of science process skills – observing, predicting, calculating, measuring etc – as outlined by Jenkins (2007). The author contends that the focus is on scientific inquiry (the adverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work). In full support to this, Milar (2004) wrote „„the idea is that students are taught to carry out their own scientific enquiries and so acquire scientific knowledge for themselves"" and that „„practical work has a central role in such vision of science education"".

In Ghana, the MOE through the CRDD (2010) provided the following suggestions for effective teaching of Biology, especially the practical work that:

> the school should establish a small botanical garden, animals in a cage, fish pond, and insects in a cage…. visiting well-established experimental and commercial farms, agricultural research institutes…. plan to visit scientific and manufacturing organizations, forest and game reserves where students will observe scientific works and application of science in manufacturing. Well-equipped laboratories will enhance teaching and learning of Biology. Well-trained laboratory technician be made available to play complementary role to the teacher.

2.4.2.2 Classes of Science Practical Work

The concept of practical work in science education goes beyond a single lesson during which participants are guided through a list of rubrics to achieve a pre-determined result. Practical work is a preferred term to laboratory work because according to Milar (2004) location is not a major aspect in distinguishing this type of activity. He argues that manipulation of artifacts or apparatus might take place both in the school laboratory or outside the school system. According to him, the term „experiment" is frequently used to denote the testing of a prior hypothesis.

Four classes of practical work in science education have been recognized by Beatty and Woolnough (1982) as:

i. Project work
ii. Demonstration

iii. Standard exercises, and

iv. Discovery experiments

Woolnough (1998) „broadcasted‟ the type of practical work that teachers perform and the reason for doing same. He reported that, according to a survey, the teachers classified practical works aimed to develop practical skills and attitude and those aimed to discover theory as most highly and much lower respectively.

Nowadays the subject matter of practical work, in a broader sense, comprises manipulations involving computerization and technological activities that are carried out within a certain period of time, normally outside the classroom setting (Kay, 2014). This idea of computer-based practical work was earlier revealed by Milar (1999) when he suggested that „„„computer-based simulations may also help to reduce the „noise‟ of the laboratory bench and focus attention on important aspects of experimental planning and data interpretation‟‟‟.Six different constituents of practical work which falls under the class of laboratory work were identified by Windschitl (2004) as:

i. Demonstration

ii. School science enquiry

iii. Skills building

iv. Discovery learning

v. Problem solving

vi. Authentic forms of enquiry

He described each of these constituents as follows in Table 1.

Table 2: The nature of different constituents of practical activity

Constituent	Description
Demonstration	Teacher leads the demonstration process by using appropriate materials and procedures
School science enquiry	Testing of hypothesis through experimental considerations making use of the scientific method
Skills building	Learners embarking on manipulative action following rubrics or engaging in cognitive skills. For example, changing a raw data into organized data for representation graphically
Discovery learning	Learners performing a task in an organized or partially organized ways to unearth an idea or a group of relations
Problem solving	Learners make use of their understanding to provide solution to a given problem
Authentic forms of enquiry	Learners engage in an independent work involving a variety of open-ended experimental investigations with little or no supervision from the facilitator.

Adapted from Windschitl, (2004)

2.4.2.3 Experimentation

Experimentation is the bedrock of scientific enquiry (Mestre, 2001). This may be the reason why much emphasis is always placed not only on laboratory but also hands-on activities as a way to produce effective tasks. Effective tasks refer to those tasks where learners are both „hands on" and „minds on" (Duckworth, 1990, cited in Milar, 2004). However, critical analysis reveals that the kind of laboratory activities students practice differs from what scientists engage in in the laboratory. Mestre (2001) outlines, in details, what scientists do in the laboratory as follows:

> Organizing an experiment starts with several questions that the scientist shows interest in. Then the scientist decides the plan to execute the experiment; apparatus need to be designed or bought; experimental procedures need to be arranged to isolate the variables to be studied; data scrutiny processes need to be outlined to isolate the relevant information from the experimental output. Findings are then analyzed and compare and contrast against result from synonymous experiments and then evaluation is performed in accordance with existing theories (p. 12).

According to him (Mestre) experimental work in science classes is unparallel to experimentation in a research laboratory. Science class experiments that are performed in the laboratory are regrettably just a cut-and-dry tasks, generally „map out‟ to verify investigated phenomena, and fundamentally not to make advertency develop hypothesis (Goldberg & Wagreich, 1990; Mestre & Lochhead; 1990). Research results put forward that laboratory task „sketched‟ to reinforce the theory learnt in lecture do yield better results than the one students study with only lecture presentation (Dubravcik, 1979, Robinson, 1979).

Mestre (2001) identifies three important functions of experimental work in science classes as follows:

i. Imparting the process of scientific enquiry;

ii. Imparting data handling, analysis and interpretation skills; and

iii. Imparting experimental skills

He argues that of these, only the last two are attainable looking at the kind of experiments that learners are engaged. He further argued that „„„teaching experimental skills and data analysis techniques are very important aspects of science instruction, and these skills can be rather difficult to teach‟‟‟. Researches prove that learners who execute hands-on laboratory practical work are better compare to those who do not, judging from exhibitions of skills such as handling of laboratory equipment, taking measurements and critical observations, data analysis and following laboratory safety protocols (Kruglak, 1952; Beasly, 1985).

2.4.2.4 Linking two Realms of Knowledge

One of the roles of practical work in science education is to guide learners make connections between two „realms" of knowledge: the realm of „bodies" and visible properties and events and the realm of ideas (Milar, Tiberghien & Marechal, 2002) as shown in figure. 1.

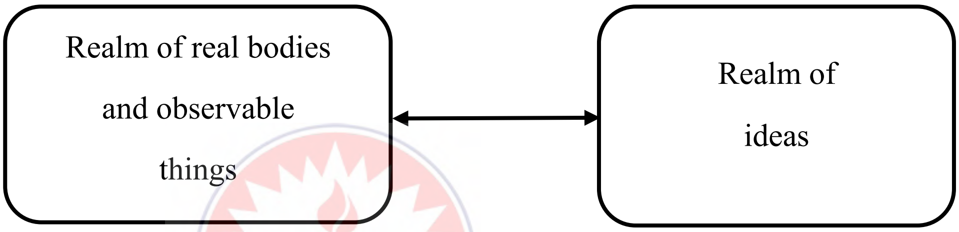

Figure 1: Practical work connecting two realms of knowledge (Adapted from Milar, et al. 2004, p. 9).

The practicability of these two realms of knowledge greatly relies on the proposed learning objectives of the work.

Table 2 outlines a method of grouping the objectives as proposed to improve the scientific knowledge of learners in a practical work.

Table 3: Objectives of practical work to improve scientific knowledge of learners by Milar (2004)

	To assist students to:
1.	Identify bodies and occurrences and become familiar with them
2.	Prove/reject a theory
3.	Learn a relationship
4.	Verify a fact(s)
5.	Conceptualize
6.	Prove/reject a hypothesis

The aim of the first objective (to identify bodies and occurrences and become familiar with them), according to Milar, is to help learners observe a material or phenomenon and be able to remember same later (Table 2). It is a „stimulant" to the recall of the other listed objectives.

Practical task in science education suggests that hands-on activities in the laboratory provide distinctive learning experiences, and for that matter should solve more peculiar objectives compare to those concerned with science education in general (Kay, 2014). Both teachers and students engaging in practical work results in a much greater progress in inculcating in learners the ability and confidence to build a strong scientific knowledge base. It looks natural, and quite obvious, to mention that learning science practical work should entail seeing, handling and manipulation of concrete objects and materials, and that imparting scientific knowledge should involve the practice of „showing" and „manipulating". For this reason, practical work is very important in science education.

Hofstein and Lunetta (2004) identify four main objectives – observation and description, arousing and sustaining science interest, personal experience opportunities with materials and logical reasoning development approach – of science practical work as suggested by teachers.

A current research by Derek Hodson outlines the five topmost reasons for the inclusion of practical activity in science education as suggested by secondary science teachers as follows:

i. Facilitate conceptualization and development
ii. Motivation through interest stimulation and enjoyment

iii. Imparting laboratory skills

iv. Providing comprehension into the scientific method and developing mastery in using it and,

v. Development of specific scientific viewpoints such as curiosity, objectivity, creativity etc (Hodson, 2005)

2.4.2.5 Improving Learners' scientific Knowledge base through Effective Practical Activity

It is important that science educators gain the requisite pedagogical knowledge and skills so that they can engage students in effective science practical work. Practical work is effective when students actually learn „„„what we intended them to learn"" (Milar, 2004). Thus, effectiveness generally points to the connector labelled (Y) in figure 2. Milar argues that for effectiveness to occur, the „task" itself must first be seen as effective at point (X) in figure 2. In other words, the learner must perform the intended task designed by the science educator. Critics reveal that practical work in science education in the laboratory is just a „direction taking" when the learners don"t see the reason *why* they are doing what they are doing (Milar, ibid). Providing comprehensive direction in totality will mean teacher"s concern regarding effectiveness at point (X) as it is a pre-requisite factor for effectiveness at point (Y) in figure 2. Effective practical work connects the physical world to scientific ideas and science will seem a repertoire of abstract ideas if without effective practical work.

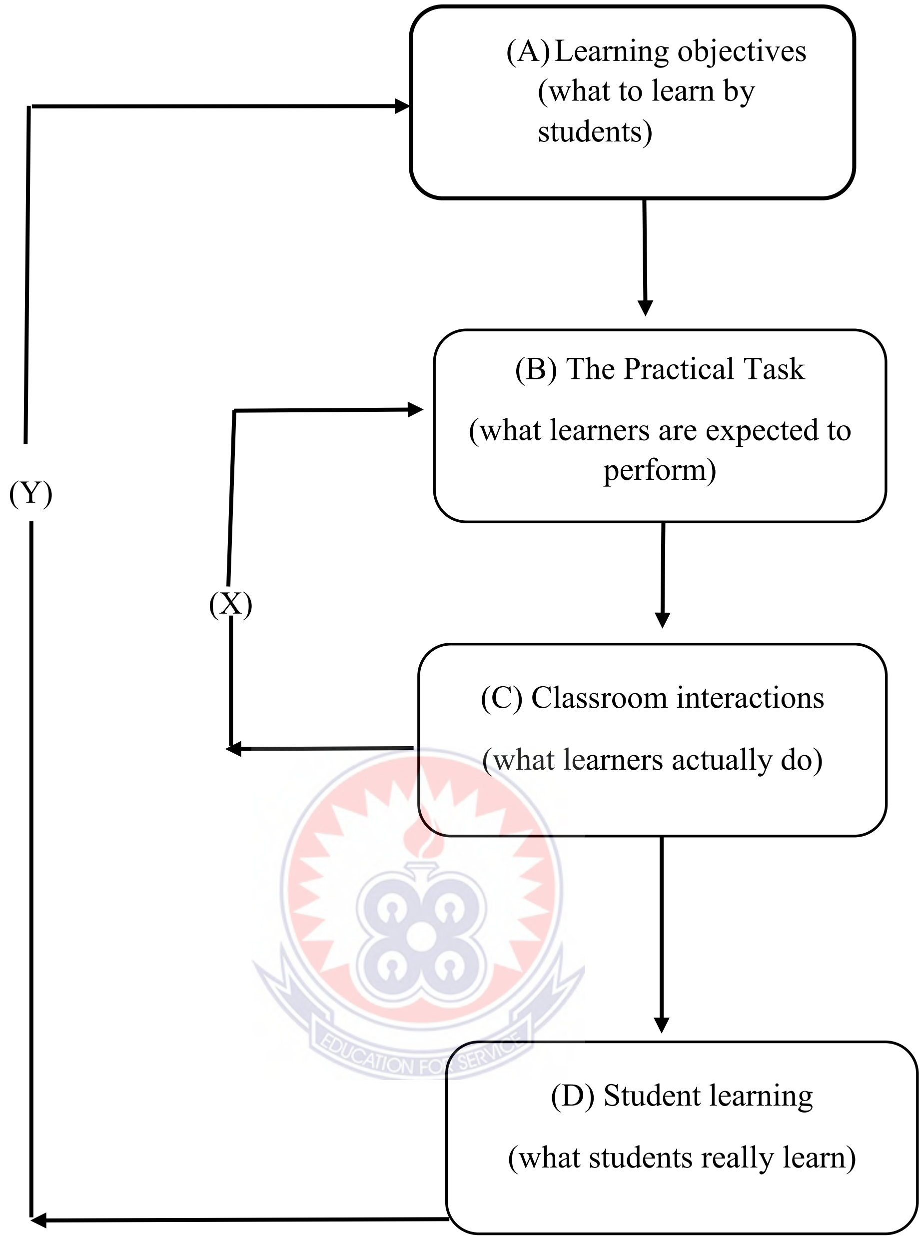

Figure 2: The process of developing and implementing a practical task

Adapted from Milar et al., 2002.

Two characteristics of effective practical work have been identified by Milar (2004). The first is that the objectives must be clearly stated in order to prevent any unnecessary ambiguity. Secondly, effective practical should outline a limited number of proposed learning outcomes. Complexity may arise and put students „at sea" when these two characteristics are not clearly defined. Firsthand information and relevant guidelines are required by students when a task requires specific skill. In cases of practical work which demands the learners to connect the realm of objects and observables to the realm of ideas, effective works are tasks which makes use of direct and organized procedures of „scaffolding" the learners" reasoning, to control and channel their analytical along productive lines.

2.4.2.6 The Role of Practical Work in Science Education

Practical work has a central role to play in science education alongside other instructional approaches. More particularly, practical work is relevant as a means to which learners have a „feel" for the difficulties of measurement. Also, practical work is a vital mechanism for instruction about experimental design. Research reveals that learners device better investigations when they competently perform them with little or no direction from the supervisor than when only tasked to outline a plan; report from experience improves design (APU, 1988).

Broadly, it is admitted that students study best by manipulation and by making available to them the opportunity to practice what they have learnt (Kolb, 1984; Moon, 2013). Besides, the ability to organize and carry out practical experiments is a basic requirement of education in the sciences (Hofstein & Lunetta, 2004; Kirschner, 1992; Kirschner & Meester, 1998).

Kirschner (1992) states three significant reasons for conducting practicals:

i. Service to theory – science practical is a means to demonstrate theories taught in other jurisdictions. In this „path" the practical becomes subservient to other approaches of teaching as well as subservient to theory, as theory and practice, actually, are interdependent.

ii. Discovery, the only channel for achieving meaningful learning – science practical work is

applied as a way to impart not only discovery learning, but also process procedures as a result of unavailability of prior theoretical context.

iii. Acts as a way to refine comprehension from empirical work – science practical work is employed to provide experience to facilitate students"" understanding of a theory. This modality accepts that significant learning can occur (i.e. students can make judgement of their own observations) without any vigorous conceptual framework.

Other researchers suggest that science practical lessons are better geared to the enhancement of particular skills (as well as to promote the development towards the teaching and learning of critical generic key skills); to study the academic procedure and to permit learners to experience phenomena (Abraham & Millar, 2008; Collis, Gibson, Hughes, Sayers & Todd, 2008). Student assessment indicates appreciation for „„„large variety of practical work"""", „„„gaining skills in the lab"""; „„„learning new techniques"""" and the „„„relaxed, informal atmosphere that encouraged individual work and investigation"""" (Mulley, 2015).

The Society of Biology, London (SBL) (2010) explains that science practical work is an important element to engage, enthuse, and inspire learners, thus stimulates lifelong interest and enjoyment in science. The SBL contends that „„„high quality, appropriate practical work is central to effective learning in science"""". The SBL identifies six importance of practical work in science education as follows:

i. Energizing creativity, curiosity and critical thinking

ii. Reinforces and encapsulate concepts, comprehension and principles

iii. Enhances learners‟ engagement with the scientific method

iv. Develops active learning and problem-solving skills in students

v. Necessitates collaborative working

vi. Identifies opportunities for students to collect and analyse information and apply mathematical techniques

2.4.3 Educational Games

2.4.3.1 Overview of Educational Games

Learning of content-rich subjects such as biology by students often results in rote memorization of concepts rather than detail understanding of the subject matter if the necessary mechanisms are not put in place. In learning such content, in most of the times, students purely memorize the subject matter without effective refinement of the knowledge (Selvi & Çoşan, 2018). Thus, the knowledge becomes temporal and easily forgotten. Learners, on the other hand, can be helped to „fly‟ above memorization to achieve an excellent level of thinking and comprehension only when they introduced to concepts through activities that involve problem-solving, enquiry skills development, group work etc in order to test their cognitive abilities. For learners to achieve such a level of understanding, science educators normally put in place classroom activities that encourage and promote active participation and learning by students, as they interact and explain concepts to one another in different ways. This is both a procedure of review and a process of necessitating thorough analysis and critical thinking (Odenweller, Hsu & Dicarlo, 1998). Educational games facilitate learners‟ active participation in the process of teaching and learning (Selvi & Çoşan, ibid).

Zirawaga, Olusanya and Maduku (2017) define a game as a "type of play where participants follow defined rules". Educational games may be viewed as application of gaming activities to assist in effective teaching and learning (Houghton, Aston, Featherstone & Perrotta, 2013). In addition to traditional methods of instruction, educational games can be employed as a supportive device to enhance learning experiences of the students, while at the same time imparting other key skills - team work, adaptation, critical thinking, creativity, observation etc – to students. Learning process should not feel boring and not just one channel of rote memorization in which participants study and achieve conceptualization through repetition (Zirawaga, Olusanya & Maduku, ibid). Science educators can take the „blessings" of the vitality and innovative thinking that is handed over by the use of technology in learning to enhance learners" performance.

A lot of different categories of educational games are available and used in educational establishments, schools, homes, recreational centres, homes and colleges. The use of games in lesson delivery always aims at improving critical thinking abilities of students while presenting a specific concept of a specific subject, by assisting learners to think deeply as they follow laid down rules and procedures. Other games such as chess have been identified as one that cannot be considered as educational games because they do not render subject content or supply curriculum material, although they enhance logic abilities, reasoning skills and other characteristics cherished in education (Yue & Zin, 2009). Educational games are those that provide subject content and/or other educational information (Michael, 2016).

Jean Piaget once outlined "play is the answer to the question: how does anything new come about?". When science educators provide the necessary platforms for and allow enough time for students‟ self-motivated play, educators are ensuring maximum development of students‟ curiosity, imagination and creativity (Elkind, 2008). Vygotsky added that, "in play a child always behaves beyond his average age, above his daily behavior; in paly it is as though he was a head taller than himself" (1978). Educational game is seen as a system where participants engage in an unnatural „dispute‟, governed by rules, producing a quantifiable outcome (Salen & Zimmerman, 2004). Two relevant concerns for „hunting‟ for the development of educational games were highlighted by Kirriemuir and McFarlane (2004) as:

i. The exploitation of motivational powers of games in making learning a fun
ii. Learning through educational games provides as effective and efficient learning device.

The fundamental aim in making educational games is to help in creating and sustaining interest and motivation of students in the learning process Hence, educational games, in addition to making learning more entertaining also encourage learners‟ in-class full participation and boost their learning attitude. Science teachers can employ scientific games for different reasons including teaching new topic or concept, underpinning a previously taught topic and motivating learners to participate in the lesson (Selvi & Çoşan, 2018).

2.4.3.2 Importance of Educational Games

Educational games are very important in facilitating self-confidence of learners (Boyle, 2011). As instructional devices, scientific games are perceived as constructive in nature because they stir up instructional methods generally considered as dull and boring (Zirawaga, Olusanya & Maduku, 2017). Scientific gaming in education provides the following advantages to the learning processes of students as outline by Zirawaga, Olusanya & Maduku (ibid):

i. Engagement of Learners

Application of technology in education has an important role of engaging learners and to encourage full participation in the teaching and learning process. The utilization of scientific games in the classroom plays a vital role in the engagement of learners by encouraging hands-on and minds-on activities. To this, Patel (2008) adds that educational games play interactive role in enhancing functional learning and motivation, and thus promoting students‟ teamwork. Scientific games have a dominant role in achieving learning as they incorporate interactive as well as distinctive elements (Selby, Walker & Diwakar, 2007).

ii. Aids Students to remember content learnt

Scientific games in education focus to assist learners recollect subject matter learnt as vigorous participation is encouraged and promoted in the classroom. Science students can rely on scientific games to remember relevant concepts, which they can make use of in examinations and to solve real-life problems. Learners who are comprehensively motivated and fully involved in the instructional process can achieve an effective learning outcome, producing a permanent „pool‟of knowledge which can later be recalled (Selby, Walker & Diwakar, ibid).

iii. Promote problem-solving skills and rule following

Scientific games such as drills operate on the principle of rule following and players (learners) are expected to strictly follow the rules in order to obtain a higher point and to progress to the next higher level. Learners can easily make use of this knowledge in a real-life situation if they are motivated by the teacher, to think critically in order to solve problems in science.

iv. Educational games are beneficial for learners with attention disorders

Educational games can be employed in the classroom as an effective tool to capture the attention of students with learning difficulties as gaming is generally considered to be a „fun" method of learning. Study indicates that web-based scientific games can aid children who experience attention challenges. Researchers have also discovered that the use of video games can assist learners overcome difficulties. For example, educational video games were found to have shown a positive correlation in promoting attention in learners with learning disabilities according to an International Journal of Environmental Research and Public Health (2021).

v. Attainment of computer literacy

21st century is generally viewed as the technological period because it makes the world a global village, most importantly in the areas of transport, education, healthcare, communication, just to mention but a few. By playing scientific games, learners develop computer knowledge and skills which will enable them prepare for the world of work. As Fafuwa (1974) put it, "you cannot use yesterday"s tool for today"s job and expect to be in business tomorrow" illustrates the fact that students must acquire computer literacy skills as it is the driving force behind today"s world of business.

vi. Promote teaching of analytical skills

Educational games can be used to impart analytical skills such as logical reasoning, critical thinking, problem solving, research, creativity, interaction and collaboration among students. Analytical skill is important in contemporary education with the aim of promoting the appropriate knowledge and skills for further professions. Richard (1999) explains that "thinking analytically is a skill like carpentry or driving a car. It can be taught, it can be learnt, and it can improve with practice ……". This assists in building broad-minded students who are capable of adapting to any real-life situation. The importance of educational games to teaching and learning is summarised in Figure 3.

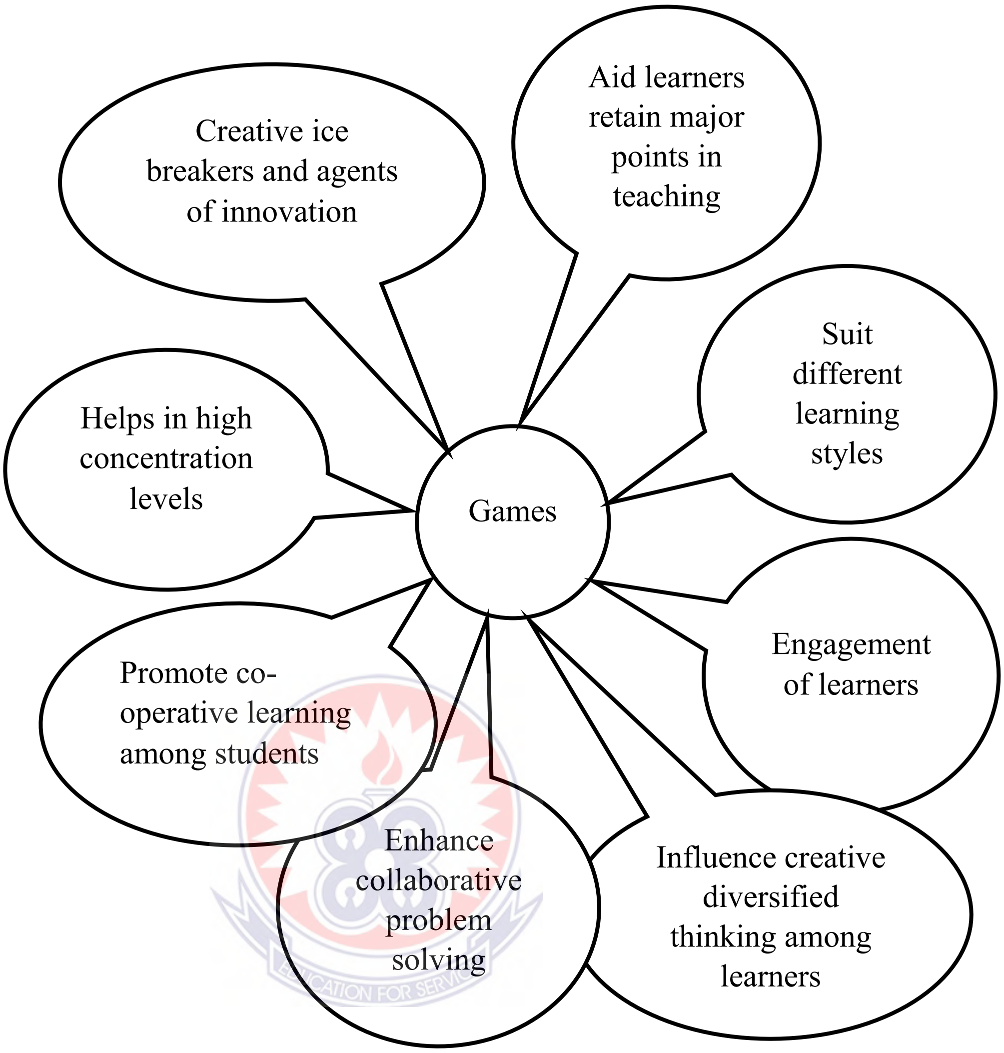

Figure 3: The role of games in education

Adapted from Boyle (2011)

2.4.3.3 Related works on Educational Games

There is a good number of studies pointing to the relevance of scientific games on students" acquisition of scientific knowledge and concepts in biology. For instance, Odenweller, Hsu and Dicarlo (1998) proved that scientific games are useful in enhancing the learning of scientific concepts and principles, and they permit learners to deliberate on target concepts. Olimpo, Davis, Lagma, Perekh and Shields (2010) revealed that learning of fundamental biological terms by students improve significantly as a result of the educational games they used in their instruction. Integrating scientific games into teaching and learning bring a significant increase in cardiology, infectious diseases and pharmacy practice assessment results (Barclay, Jeffres & Bhakta, 2011). Again, according to Ogershok and Cottrell (2004), educational games inspired learners to boost their knowledge of pediatric medicine. Bhaskar (2014) put forward that gaming in education assisted learners better their comprehension of blood groups to assess their existing knowledge. Carew (2018), argued that games are an effective method for understanding of physiology. Osier (2014) pointed out that scientific games have a remarkable effect on learners‟ achievement in genetic terms. Selvi and Çoşan (2018) revealed that using scientific educational games facilitates students‟ academic performance and retention of knowledge in kingdoms of living things. Al-Tarawneh (2016) indicates that educational games contribute significantly to students‟ scientific concepts acquisition. Results from all these studies with different categories of students from different locations in different aspects of biology show that educational games can be employed in the classroom as an effective tool to complement and supplement conventional method of instruction to improve students‟ learning processes.

Educational games are generally considered as an important substitute to support traditional teaching method as far as instructor‟s responsibility is concern, such as motivating students to learn, assisting them admire learning, and making learning a hobby. Such responsibilities are more often than not relegated in science instruction because learners‟ inspiration and involvement in lessons is generally a herculean activity for in-class instructing. Nevertheless, learners become extremely active to learn when the learning activity is carried out in a pleasurable and interactive way.

2.5 Multimodal Teaching Strategies and Students' Academic Performance

Teaching is an act of facilitating students‟ learning through a proper management, by the science educator, of the interrelationships among the students‟ interests, the content for learning, and the methods and materials he/she uses in the teaching and learning of the subject content (Abimbola, 2009). Multimodal teaching strategies simply refer to a combination of carefully designed modes that could be followed to teach the same topic, concept or idea. These include the use of video, online classroom, scientific games, practical etc.

Teaching strategies may be classified on a continuum with extremes which may be viewed as expository, „chalk and talk‟ and inquiry guided discovery teaching (Padilla, Okey & Dillashaw, 1983). The authors described the traditional „chalk and talk‟ mode as a teaching strategy where the instructor performs a role as the interpreter of natural occurrences for the learners and the channel through which all information is passed. In the framework of pre-technology education, the science educator is the sender, the curriculum material is the message and the receivers are the learners is the mode of information delivery via chalk and talk strategy.

Fundamentally, the teacher exercises control over the teaching and learning process, the subject content is presented to the whole class and the teacher tends to emphasize factual knowledge. The teacher presents the lesson content and the learners listen, thus, learning becomes passive and the students play a little role in the learning process. Extensively, the traditional lecture method of instruction in the classroom is of less effectiveness in the teaching and learning of science in our institutions. The use of MIA may not appear new, but its implementation may be out of ordinary in the field of study. It is a form of educational technology with its approach to teaching that results in a transformation and educational experiences for the learners. Most science educators use inappropriate method(s) to teach science concepts, terminologies and/or topics.

Many experts have pinpointed the apparent incompetence of many science students to engage in complex problem-solving tasks and utilize school knowledge to real life challenges after the school settings (Akpan, 1996). He again stated that what science educators and educational institutions face is a rudimentary redefinition of what it implies to be a learner and a teacher. Most science educators must acknowledge that changes in the learning outcomes of students must be supported with a corresponding change in the curriculum and instructional approaches (Oludipe & Oludipe, 2010). The authors further contended that it is obvious many instructors of nowadays find themselves in the midst of changes for which they are not professionally trained for. Many of these teachers in our schools today were trained in schools where the role of the learners is to rote memorize information, perform well-coordinated experiments, compute mathematical calculations and were assessed on their ability to reproduce the activities or remember the specific concepts (Gbadamosi, 2013).

Furthermore, the traditional methods of teaching science by teachers as the only information providers to learners appear outmoded. In a study conducted by Colburn (2000) on university undergraduate students, the result unearthed that just 20% of the students retained the content taught, as they appeared very engaged in notes writing to internalize the material. After few minutes into the lesson, only 15% of them were paying attention. Most science educators teach science subjects – chemistry, physics, biology, integrated science - using inappropriate methods such as lecture, chalk and talk etc, to the neglect of appropriate laboratory practical, scientific games or discovery method, which are more suitable for teaching the subjects (Bello 1995). Some instructional strategies appear more facilitative than others in teaching science, but the choice of a method depends on the topic or concept. The efficacy of a teaching method and its appropriateness in certain instances is a function of its selection by the teacher. Achor (2008), states that some teaching methods are students centered, interest sustaining and activity oriented, and in teaching science educators are required to integrate a number of them.

Oludipe and Oludipe (2010), conducted a research on the impact of constructivist-based teaching approaches on the academic achievement of students in integrated science. Research instruments used were pre-test, post-test and delayed post-test conducted 2 weeks after the administration of the post-test to answer the question as to whether the students memorization of facts or comprehension of different concepts taught by the teacher using different methodologies impacted retention. The sample size used in the study is made up of 120 Junior Secondary School III Students randomized from 4 public secondary schools in Ijebu Ode Local Government of Ogun State. The result revealed that the students exposed to the constructivist approach outperformed their colleagues taught by lecture method in both post-test and delayed post-test; they (Oludipe & Oludipe) concluded that accordingly, if constructivism is employed to instruct learners integrated science, it will result in improved academic performance of students in the subject.

A research conducted by Yusuf and Afolabi (2010) on the impact of computer assisted instructions in multimodal structure on secondary school students in biology with a sample size of 120 year one secondary school students from 3 private-owned schools in Oyo State. The authors used two-group pretest-posttest control and experimental group design. Analysis of the research findings showed that performance of the experimental group of students either individually or collectively outperformed the control group exposed to conventional classroom instruction. They recommended the need to incorporate computer assisted instruction packages in multimodal form for the teaching of biology in Nigerian secondary schools.

Muraina, Adegboye, Adegoke and Oligido (2019) carried out a survey on "Multimodal Instructional Approach: The Use of Videos. Games, Practical and Online Classroom to Enhance Students" Performance in Programming Languages wit degree students forming the target population. Data collection was in three bases: data for videos and games, data for practical activities and data for online classroom. Quantitative analysis of the data showed that the employment of multimodality for teaching to promote learning programming language provides teachers the platform to assist students gain nuanced comprehension of codes, meaningfully understand what they learned and brilliantly uncover a psychological sanctuary. More interestingly, the authors found multimodal teaching approach to have strengthened "programming sense of accomplishment and self-esteem".

Ari and DwiMaryono (2016) conducted a study on robomind utilization to improve student motivation and concept in programme learning. The objective of the research is how best to employ robomind as a device to motivate learners in learning programming in computer science. Robomind is a simple scientific programming environment having its own scripting language system that allows students to study the basis of computer science by programming a simulated robot. It also aims of providing insights into robotics and artificial intelligence by the assistance of a software tool used for concept learning, logical reasoning and problem-solving. This study is motivated by the lack of learner motivation in learning programming as a result of the initial perception in seeing programming as difficult. Research respondents were first introduced to robomind before Pascal programming language. Results from data analysis provides that the methodology is effective in enhancing students‟ conceptualization of robomind utilization in learning programming.

A research conducted by Gbadamosi (2013) involving teachers‟ awareness and utilization of innovative teaching strategies, including MIA sampled 300 biology teachers as research subjects. The findings of the research show that biology educators in Oyo South Senatorial District are highly aware of the chosen innovative teaching strategies with the scoring awareness being 88.0%. The research therefore recommends workshops and seminars for in-service teachers to sharpen their repertoire of knowledge and skills in the implementation of the strategies in their instructions.

Lirola (2016) researched on a topic "the importance of promoting multimodal teaching in the foreign language classroom for the acquisition of social competencies" highlighted the use of multimodal resources such as texts, videos, scientific games, practical etc on social topics to institute cultural characteristics in a language discipline and to reinforce into the various social accomplishment university students can gain when they work with them. The research focuses on the underlisted research questions: "how can multimodal texts and resources contribute to the development of the five skills in a foreign language classroom"? and "what are the main social competencies that students acquire when the teaching-learning process is multimodal"?. Analysis of the findings reveals the major competencies that the students develop as a result of multimodal teaching.

A research into undergraduate students assessment of the application of IT to physics education was conducted by Omosewo (2012). Eighty-five (85) final year students of Educational Technology of University of Ilorin who minored in Introductory Technology were selected as research subjects. Research instrument was structured questionnaire. It was revealed that 96% of the respondents supported the use of IT as a method of teaching science which will help accelerate cognitive development of the learners while 88% maintained that affective domain would be enhanced. 94% contended that psychomotor skills will be improved and 85% suggested that computer assisted instructions should be used because this is the era of computer literacy. These packages are mentioned to include the use of visuals, computer graphics, projected media and videotapes (Gbadamosi, 2013).

The issue of multimodality in the standpoint of the myriad of representations and of description forms in science education has been the entity of attention and interest of the academic circle and referred to as the "third wave of scientific literacy" (Klein & Kirkpatrick, 2010), cited in Arroio & Souza, 2012). In teaching terms, the institution into the sphere of science education is in charge of teacher who leads the action of institution, i.e., the science educator, extending the connotation and its interconnections through the task with the language and ordering the process by which persons generate meaning.

According to Jewitt (2006),

> "the interpretative work of students is reshaped through their engagement with a range of modes, images, animation, hypertext, and layered multimodal texts. In such a view, students need to learn how to recognize what is salient in a complex multimodal text, how to read across the modal elements in a textbook

> or IWB, how to move from the representation of phenomenon in an animation to a static image or written paragraph, and how to navigate through the multiple paths of a text. These complex task – as against traditional taxonomies of print skills – are central to multimodal learning and development. Learning increasingly involves students in working across different sites of expression, negotiating and creating new flexible spaces for planning, thinking, hypothesizing, testing designing, and realizing ideas".

2.6 Cognitive Load Theory and Multimodality

Sweller (1980) developed cognitive load theory (CLT) while studying problem solving. He noticed that problem solving requires a relatively large amount of cognitive processing capacity, which may not be devoted to schema construction. The theory employs aspects of information processing to emphasise the inherent limitations of concurrent working memory load on learning during instruction. CLT has been designed to provide guidelines intended to assist in the presentation of information in a manner that encourages learner activities that optimizes intellectual performance. CLT is based on a number of widely accepted theories about how human brains process and store information (Gerjets, Scheiter & Cierniak 2009)

Chandler and Sweller (1991) propounded that CLT explains that effective classroom teaching and learning resources facilitates learning by directing cognitive materials towards activities that are important to learning. During complex learning, the quantity of information that must be processed at any point in time have the potential to affect the functioning memory capacity in which the individual must processes all relevant information before any significant learning can take place (Paas, Renkel & Sweller, 2004). These authors further stated the cognitive operation underlying the theory – CLT largely deals with the learning of multiplex cognitive activities, where students are often devastated by the large number of information tasks and their interconnections that need to be treated simultaneously before significant intellectual learning can start. Teaching techniques to curtail this high load, in an attempt to achieve significant learning in multiplex cognitive realm, has emerged the focal point of CLT. The theory advocates that significant learning occurs best under circumstances that are oriented with student cognitive architectonics (p.12). For this to be effectively responded to and work to lessen massive cognitive loads in an attempt to process new information, different methodologies have been designed and tested to hit the maximum point for cognitive load on memory as students learn new information. For instance, Mayer and Moreno (2003) stated that pre-training consequences within learning activities with multimodality, communicated a healthier transfer result and a degree of one‟s cognitive load effect when fundamental comprehension is well entrenched. Mayer and Moreno suggest that science teachers must effectively apply technology by applying it in course of actions that are landed in a research-based postulation of how students learn. Hence, improving upon the CLT, they advanced a research grounded mini-theory called the Cognitive Theory of Multimedia Learning, CTML. The CTML is derived from elementary theories, for instance "the dual coding theory, the accepted model of working memory and the cognitive load theory" (Suflita, 2012) to ascertain that the student employs a visual information processing arrangement that catalyses animation and a verbal data processing arrangement that assimilates auditory information. During multimodal learning the student passes through a stand of cognitive mechanisms that is made up of selecting, organising and integrating. Essentially, multimodal learning allows the student select important terms and representations, organize them together and then integrate them with previous knowledge for meaningful learning to occur.

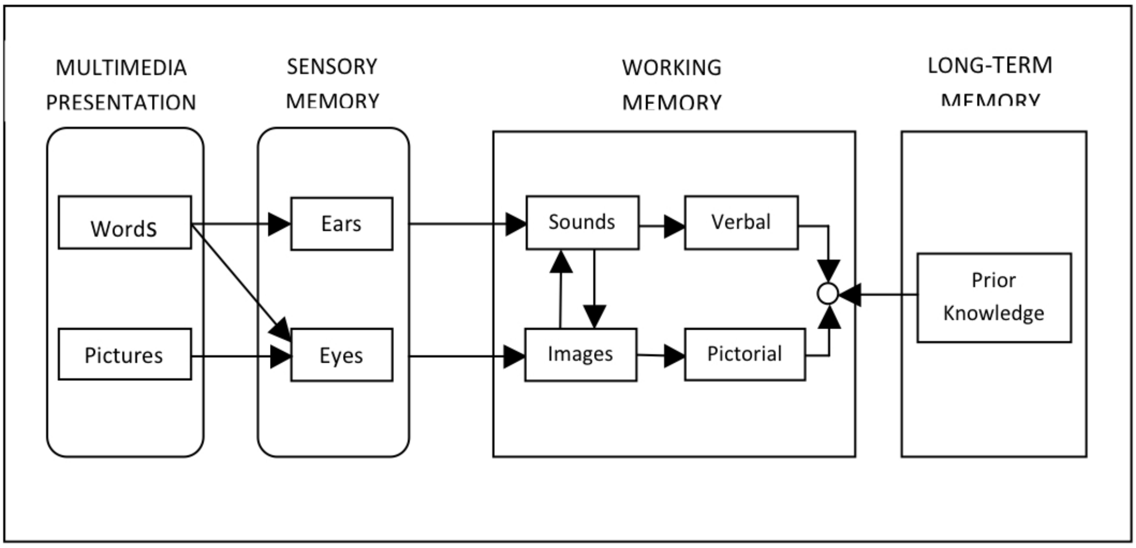

Figure 4: Illustration of visual representation of the CTML. Adapted from Suflita, 2012

This figure 4 was founded on three principal premises gathered from the elementary theories that validate multimodal learning by Mayer (2001) which include:

i. Visual and auditory inputs in a form of information are separately processed along different mechanisms of processing information

ii. Each input processing mechanism is restricted in its ability to process the input

iii. Processing inputs in the mechanisms constitutes an active process designed to build consistent intellectual representations.

Rias and Zaman (2011) developed seven principles of multimodal learning based on Mayer"s research and other multimodal learning theories. This is summarised as follows:

i. Multimedia principle: students learning is enhanced from words and pictures than from words only

ii. Spatial contiguity principle: students learning is enhanced when corresponding words and pictures are presented near instead of far from each other on a page or screen

iii. Temporal contiguity principle: students learning is enhanced when corresponding words and pictures are presented simultaneously instead of successively

iv. Coherence principle: students learning is enhanced when extraneous words, pictures and sounds are excluded instead of included

v. Modality principle: students learning is enhanced from animation and narration instead of animation and on-screen texts

vi. Redundancy principle: students learning is enhanced from animation and narration instead of animation, narration and on-screen texts

vii. Individual differences principle: design effects are stronger for low-knowledge learners than for high-knowledge learners and for high spatial-learners rather than low-spatial learners (Suflita, 2012).

In relation to classroom connection, Moreno (2006) propounds a learning base premises that connect other researches in the areas of cognitive science. These generally accepted learning premises can be used as multimedia, and multiple modes are integrated effectively in the instructional methodology and function as specifications for effective teaching. He (Moreno) explains that:

i. Learning commences as information is refined in different mechanisms for various sensory procedures;

ii. Just a very few units of information can be purposively processed in the working memory at a certain point in time;

iii. Long-term memory contains a huge number of ordered schemas;

iv. Comprehension may be captured in long-term memory in both verbal and non-verbal keys;

v. Adequate practices promote operation of schemas under automatic processing;

vi. Purposeful attempts need to be spent in selecting, organizing and integrating the in-coming information with exiting knowledge.

2.6.1 Multimodal and Multimedia Design

Multimodality and its associated multimedia design are useful for science instruction in the classroom because learners set foot in the classroom with each having a unique level of competence both with content and with media utilization (McGinnis, 2007). This multiplicity spontaneously allows for interaction among students and transfer knowledge from each other while providing the science educator with numerous opportunities to metamorphose both content and instructional strategy. Social worlds of learners is a factor of much consideration as multimodal implementations are linked to wider social, cultural and global settings. One broadscale target of science education is to adequately prepare learners with skills, dexterity and “science knowledge for interaction in the global landscape of the future” (Suflita, 2012).

According to Gainer (2010), humans live in an era of multimedia in which the flow of o information comes less frequently from print origin and more generally from exceedingly constructed visual images, complex sound harmonization and diverse media formats. This multimodal-multimedia arrangement promotes effective interaction and adaptation among students. As Suflita (2012) expresses, “by providing learning environments that are multimodal and in nature within the classroom, students are best adapted for the diverse and ever-changing learning environments that they are most likely to encounter in education, the workforce and society". As learners are exposed to, acquainted with and well versed in multimodal and multimedia building, this strategy will favourably add their skills of critical thinking, problem solving and enquiry. Creativity, in general, is as important as enquiry skills and critical thinking. It has powerful relationships with motivation resulting in learners that are engross with the content and learning as a whole. In terms of creativity, Walsh (2007) explains that students have the skills and expertise to integrate their visualization with the numerous modes of the classroom, which in general prepares students to be learners of multimodality. The use of modes- print, visual and digital – assist learners relate their understanding in new science contexts. When science educators are clever to exploit and roll in students non-content techniques to promote learning of the content, learners may have a broader freehold in their learning. Again, this method of projecting different modes in the lesson guides students to transfer their relevant previous knowledge, skills and attitudes to new contents (Suflita, ibid). Walsh again explains that learners are multimodal architects and that creativity advantages offered by it, it allows them to develop sensical responses to the subject matter. The rationale of effective science instruction is to involve and challenge learners to be participants and interactive with the teaching and learning process. Even though strategies like enquiry and technology are relevant to student engagement with the subject matter and ordinarily entail multimodal features, explicitly integrating modes within these individual environs will render an excellent representation of the subject matter and can typically differentiate the learning.

Interpretation from Jewitt (2008) study that, "all modes are communication but all modes are partial, underscores the fact that modes not only construct meanings in different ways but also relay and transfer various meanings through their distinctive affordances" (Suflita, 2012). Motion between print to kinesthetic or visual o written modes can challenge learners in new paths that a singular strategy or mode alone cannot accomplish. Technology by definition has multiple modes that are frequently transforming, and it is specifically the aforementioned technology that can institute an engaging, delightful, differentiated instruction and multimodal learning environment to motivate learners as they maneuver their comprehension through innumerable modes.

2.7 Implications for the Science Classroom

Additional advantages that an explicit multimodal technique in science education can furnish include assisting to attain each learner‟s interests and learning methodologies (Suflita, 2012). Higher degrees of learning can be achieved if science educator is committed to developing an engaging instruction and structuring and re-structuring multimodal experiences and feedbacks in which learners make the interconnections and appraise inconsistencies across diverse forms of representation. As explained by Bezemer and Kress (2008), apart from multimodal technique being additionally closely align with learners‟ social learning sphere outside the school system, science educators can utilize this approach to relay students‟ understanding into the

Less frequently used literacies such as writing and reading. A multimodal strategy can materially influence learner engagement and learning as there are several opportunities to re-echo the content with the learners. Jewitt (2008) outlines that meanings are constructed, conveyed, translated and reconstructed (Suflita, 2012).

Multimodal approach goes beyond just transmitting information using diverse channels, but demanding learners to discover learning through these multiple modes by applying their skills and to exploit their interest as they interact with the content and learning opportunities available to them. Achieving this broad objective on information assembling and activation, students‟ understandings concerning the act of learning are more likely to improve drastically. If science teachers can adjust how learners become engaged with the subject matter knowledge or summons their views of what constitute acceptable knowledge and not just correct answer, then learners may be exposed not only to the process of perfect learning but also promoting the development of skills that are esteemed beyond the questions of a test or the boundaries of the classroom. Thus, this sequence of "engagement-perceptions-learning" according to Suflita, can be broadened to allow learners critically assess resources, analyze formats and examine representations to communicate more effectively and to challenge how knowledge is constituted in order to personalize their learning. Through comprehension in many disciplines including science, psychology, arts, mathematics etc., multimodality is exposing its broad impact. Jewitt (ibid), as he tries to develop a clear definition for multimodality, praises it for its implications on pedagogy. He argues that, globally, people are trusting and adapting to the switch from print to digital channels and its implications concerning dissemination and information transfer which happens more appropriately with varied and global audience. By this strategy of using multiple modes, learners engagement and sustenance of interest may potentially rise which would facilitate motivation and learning for comprehension far from the walls of the content knowledge.

2.8 Conceptual Framework

The construction of a conceptual framework should point to the elements that are most relevant in addition to the connections that are proposed to convey meaning to the subject of interest under study (Miles & Huberman, 1994). This framework takes into consideration the knowledge categories from the work of Shulman (1986) and Windschitl (2004) as outlined in Figure 5.

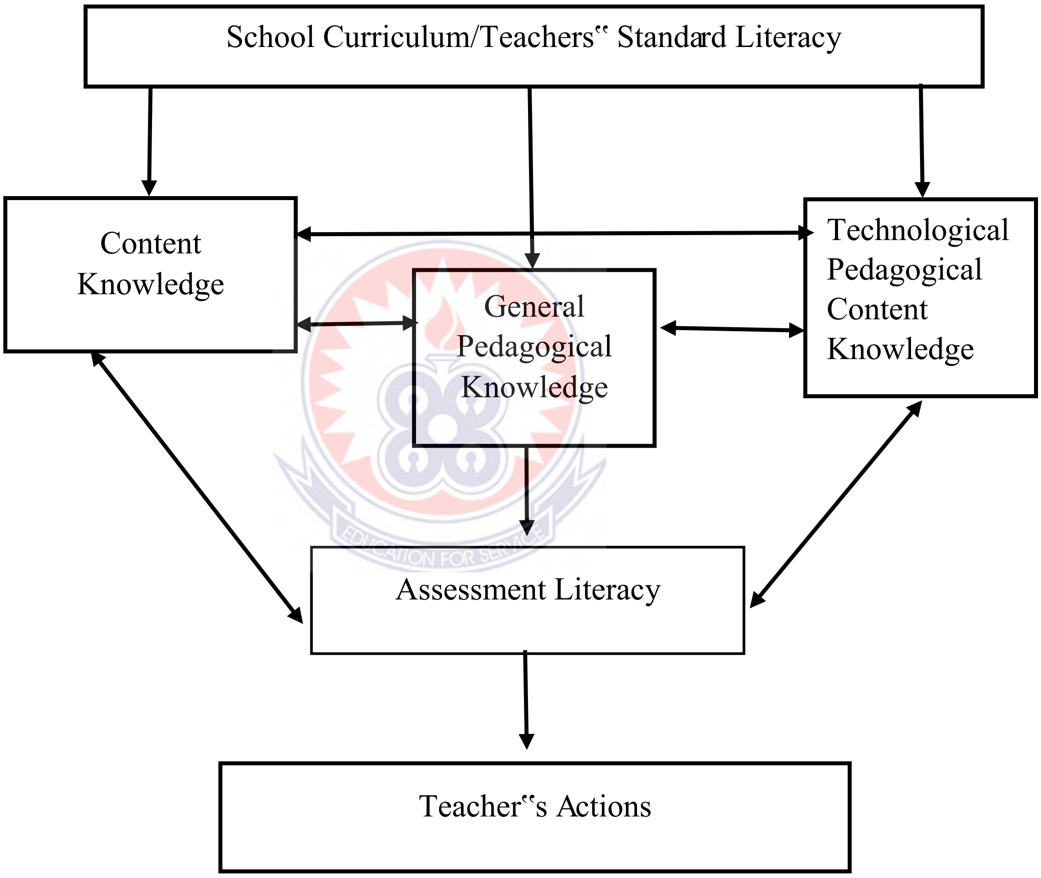

Figure 5: Conceptual Framework

A brief explanation of each of these knowledge categories is provided below for easy clarification.

Teachers" Standard Literacy

Teachers" standards literacy are explicit expectations of skills and techniques that all teachers should be able to exhibit. These standards may be used in schools, Continuous Professional Development (CPD) as individual, school or cluster-based level, training and self-development (NTC, 2017). The standards are grouped into three main categories – professional values and attitudes, professional knowledge and professional practice – each having its own sub-divisions.

For the purpose of this research, five out of the six (6) sub-divisions of professional knowledge which are relevant to this study is outlined. Thus, according to NTC, the teacher:

i. "demonstrates familiarity with the education system and key policies guiding it;
ii. Has comprehensive knowledge of the official school curriculum, including learning outcomes;
iii. Has secure content knowledge, pedagogical knowledge and pedagogical content knowledge for the school and grade they teach in;
iv. Understands how children develop and learn in diverse contexts and applies this in his or her teaching; and
v. Takes accounts of and respects learners" cultural, linguistic and socio-economic and educational backgrounds in planning and teaching".

School Curriculum Literacy

According to Tanner and Tanner (1995), curriculum is a "plan or program of all experiences which the learner encounters under the direction of the school"". It is "the totality of the experiences of children for which the schools are responsible (Gatawa, cited SADC, 2000). Curriculum may bring together the proposed interaction of students with teaching content, materials and resources and procedures for assessing the attainment of laid down objectives.

Putting the above definitions and explanations together, curriculum is perceived as a composite unit which embraces the student, the educator, teaching and learning strategies, anticipated and unanticipated experiences and work output within a school setting (SADC, 2000).

The curriculum comprises both the vertical and horizontal dimensions, as well as its saliency (Shulman, 1986) and (Rollnick et al., 2008) respectively. Vertical curriculum refers to the officially sanctioned curriculum at grade stages below and above, in addition to the specific grade stage at which the teacher teaches. Horizontal curriculum on the other hand refers to the knowledge about the relationship of science topics at a specific grade stage and the understanding of the syllabus of other related subjects at the same grade stage. The instructor‟s option to exclude certain areas of a specific and/or to include other areas or covering certain sections of a topic in a contrasting manner to that sanctioned describes the instructor‟s saliency as Rollnick, (ibid) described it as "…. the teacher‟s understanding of the place of a topic in the curriculum and the purposes of teaching it"".

Content Knowledge

Content knowledge represents the knowledge of subject matter into an understanding of how relevant concepts of the subject are organized and how they are applied in the curriculum materials, as well as the design and effective selection of instructional resources (NTECF, 2017). Windschitl (2004) sees content knowledge as a comprehensive understanding of scientific facts, theories, principles, laws, history and conceptualization of processes and procedures relating to the nature of science, scientific enquiry and the skills and techniques to undertake such enquiries. Shulman (2015) defines pedagogical content knowledge as "teacher‟s interpretations and transformations of subject matter knowledge in the context of facilitating students learning"".

General Pedagogical Knowledge (GPK)

The MOE through the NTECF (2017) explains the GPK as follows:

> General Pedagogical Knowledge refers to the principles and strategies of classroom management and organisation, teaching methods, assessment, learning processes and learner characteristics that are cross-curriculum. The rationale for pedagogical literacy is to help the teacher understand how to teach and assess the subjects that schools offer and their pedagogical approaches in the context of the school and the learner. Pedagogical knowledge makes the teacher sees the linkages among student, context, subject discipline and the pedagogical approach. Teachers‟ PK is the „how‟ of teaching and it includes knowledge of different theories about learning, learning styles, learners‟ context, planning and management, and evaluation (pg. 28).

Technological Pedagogical Content Knowledge (TPCK)

TPCK, also known as TPACK, refers to the structure that combines teacher‟s knowledge of educational technologies and his/her PCK to produce effective and instruction using contemporary technologies (NTECF, 2017). It focuses mainly on technological instructional strategies.

Knowledge of Assessment

NTECF (ibid) defines assessment as a "systematic process through which the progress and achievements of a learner or learners is measured or judged in compliance with specific quality criteria"". It refers to the various forms of formative and summative tasks, means of obtaining conceptions and skills, means of acknowledging the limitations of students" comprehension and deficiencies in their problem-solving techniques (Windschitl, 2004). The teacher needs to be equipped to identify the needs of all students and be conversant with the fundamentals of assessment and testing.

CHAPTER THREE

METHODOLOGY

3.0 Overview

Chapter three discusses the methods and strategic procedures adopted to obtain the necessary information relevant for this research work. Thus, the type of research design, study area and sample size and sampling techniques were outlined. The chapter comprehensively discussed instrumentation, instrument validity and reliability, intervention as well as procedure for data collection and analysis and ethical consideration associated with the study.

3.1 Research Design

In this research work, the quasi-experimental research design is employed, i.e., two group pre-test - post-test design as shown in Table 3. Thus, quasi-experimental research is a research that resembles experimental research but is not a true experimental research. Although the independent variable is manipulated, participants are not randomly assigned to conditions or orders of conditions (Cook & Campbell, 1979). Quasi-experiments are best assigned in settings where random assignment of participants of the research is very difficult or may not be possible. They are often conducted to evaluate the effectiveness of a treatment/intervention. Creswell (2012) states that experiment is used when the researcher wants to establish possible cause and effect connections between unconventional and conventional factors. He further states that the researcher must control all the variables that influence the outcome except for the independent variable. So that when the unconventional factor influences the conventional facotor, we can say the unconventional factor caused or probably caused the conventional factor.

Table 4: The two-group pre-test and post-test design.

E_1: T1	Exp. Grp. (X)	T2
C_1: T1	Con. Grp. (C)	T2

Where:

E_1 is the experimental group

X is the treatment (conventional method of teaching plus MIA) for the experimental group

T1 is the pre-test

T2 is the post-test

C_1 is the control group

C is the treatment (only conventional method of teaching) for the control group

3.2 Setting

The research setting for this quasi-experimental study is a large public Senior High School (Nifa Senior High School). The school is located in a quiet neighbourhood setting of Adukrom in the Okere District of Eastern Region of Ghana with approximately 2791 of student population and 126 teachers. The school is one of the three public second cycle institutions in the district. It is a mixed school, running both boarding and day systems with diverse classroom population of students coming with different economic and ethnic backgrounds. The population of the district is sixty five thousand and sixty five (65, 065) according to 2010 Population and Housing Census records, with an annual growth rate projected to be 2.4%. Adukrom is the capital of the Okyere District which is located between latitude 6.0154° and 6.0554°N of equator and longitude -0.0834° and 0.503°W of Greenwich Meridian and on an elevation of 448m above sea level. According to the District Assistant Statistician, Justine E. Darkey, the district was created out of Akuapem North Municipality in

2017 and lies within the semi-deciduous forest zone of the country with temperature between 20°C in August and 32°C in March averaging 23.88°C. The district covers an area of 255 km^2 and is inhabited by the Kyerepongs, Akwapims and other minor ethnic groups such as the Krobos, the Ewes and the Northerners (Personal communications with Mr Providence Nyonyo). The major economic activities of the indigenes are agriculture, commerce and stone quarrying.

3.3 Target Population of the Study

Science students of Nifa Senior High School formed the target population for this quasi-experimental study. This population was made up of 111 male students and 409 female students making a total target population of 520.

3.4 Accessible Population of the Study

The accessible population of the study is the second year science students of the school. The total number was calculated to be 148 students.

3.5 Sampling Technique

In this quantitative research work, I used stratified random sampling technique to sample students. It is a type of sampling technique in which the population is divided into smaller strata to complete the sampling process. Stratified random sampling technique is a strategy used by many researchers to guarantee the inclusion in the sample all identified sub-groups in the population.

3.6 Participants of the Study

Fifty 2nd year science students from Nifa Senior High School participated in the study. Twenty-five students were placed in each of the experimental and control groug. The experimental group comprises of 11 and 14 male and female students respectively while the control group consists of 13 and 12 male and female students respectively as shown in Table 5. The ages of the students ranged from 16 -18 years.

Table 5: Distribution of participants according to group and gender

Group/Gender	Male	Female	Total
Experimental	11	14	25
Control	13	12	25
Total	**24**	**26**	**50**

3.7 Instrumentation

The research instruments for this study were The Conceptual Understanding Test (CUT), Knowledge Retention Test (KRT), open-ended focus group interviews and observation. These instruments were designed and administered by the researcher and are collectively known as Multimodal Instructional Approach Instrument (MIAI). The combination of these approaches for data collection is to ensure triangulation of the data collected. Pre-test was however conducted prior to the intervention to ensure parity of the groups.

3.7.1 Photosynthesis and Mineral Nutrition CUT/post-test

In the process of developing and constructing the test, a table of specifications showing the objectives of the photosynthesis and mineral nutrition unit in the SHS biology syllabus was developed. The highest score in CUT is 80. Questions were fairly distributed in terms of the learning objectives to the entire unit. The CUT consisted of 33 items assessing four degrees of objectives in cognitive domain, i.e., knowledge, comprehension, application and evaluation. These were reflected in the four types of questions making up the test:

i. Fill-in the blanks questions (12 items)
ii. True or false questions (3 items)
iii. Multiple choice questions (14 items)
iv. Essay type questions (4 items)

3.7.2 Knowledge Retention Test

The Knowledge Retention Test, KRT was developed by careful selection of test items from the pre-test items and CUT items, in addition to few new items. It assessed four degrees of objectives in cognitive domain, i.e., knowledge, comprehension, application and analysis. The highest score in KRT is 50. The KRT is made up of 20 test items which assessed students" ability to recall information learnt in some few weeks in the past. The KRT comprises the following areas:

i. Multiple choice questions (7 test items)
ii. Fill-in the blanks (6 test items)
iii. Essay type questions (7 test items)

3.7.3 Interview Schedule

Open-ended interview questions were developed for focus group interview. Creswell (2012) argues that "usually open-ended questions are asked during interviews in hopes of obtaining impartial answers". The interview seeks to investigate the perceptions of learners on the use of MIA in learning photosynthesis and mineral nutrition.

3.7.4 Observation

Observation protocol was prepared and followed strictly to observe the actions of the respondents during the intervention period.

3.8 Instruments Validity

To ensure the validity of the CUT, it was presented to the researcher‟s supervisor and two other SHS biology teachers for review. Based on their recommendations some items were amended especially with regard to scientific wording of the items. Thus, two items were completely deleted paving way for the test with 33 items. Also, one English language teacher analysed the questions with reference to language and expression. Based on his feedback, relevant adjustments were effected to the test.

Interview instruments were also validated and approved by a PhD Biology student, who is also a tutor at a College of Education and colleague researchers with respect to content and face validity. He reframed and restructured some of the instruments in order to prevent ambiguity.

3.9 Instrument Reliability

To ensure reliability of the CUT, the instrument was subjected to test-retest reliability method so as to ascertain the fact that the data collection procedure is compatible, steady and repeatable. The instrument was given to a colleagues Biology teacher who tested and retested with the SHS three science students within an interval of four weeks. The reliability coefficient was computed using the simple linear correlation coefficient formula and the value obtained was 0.82. This value shows a strong correlation, meaning that the research instrument is reliable.

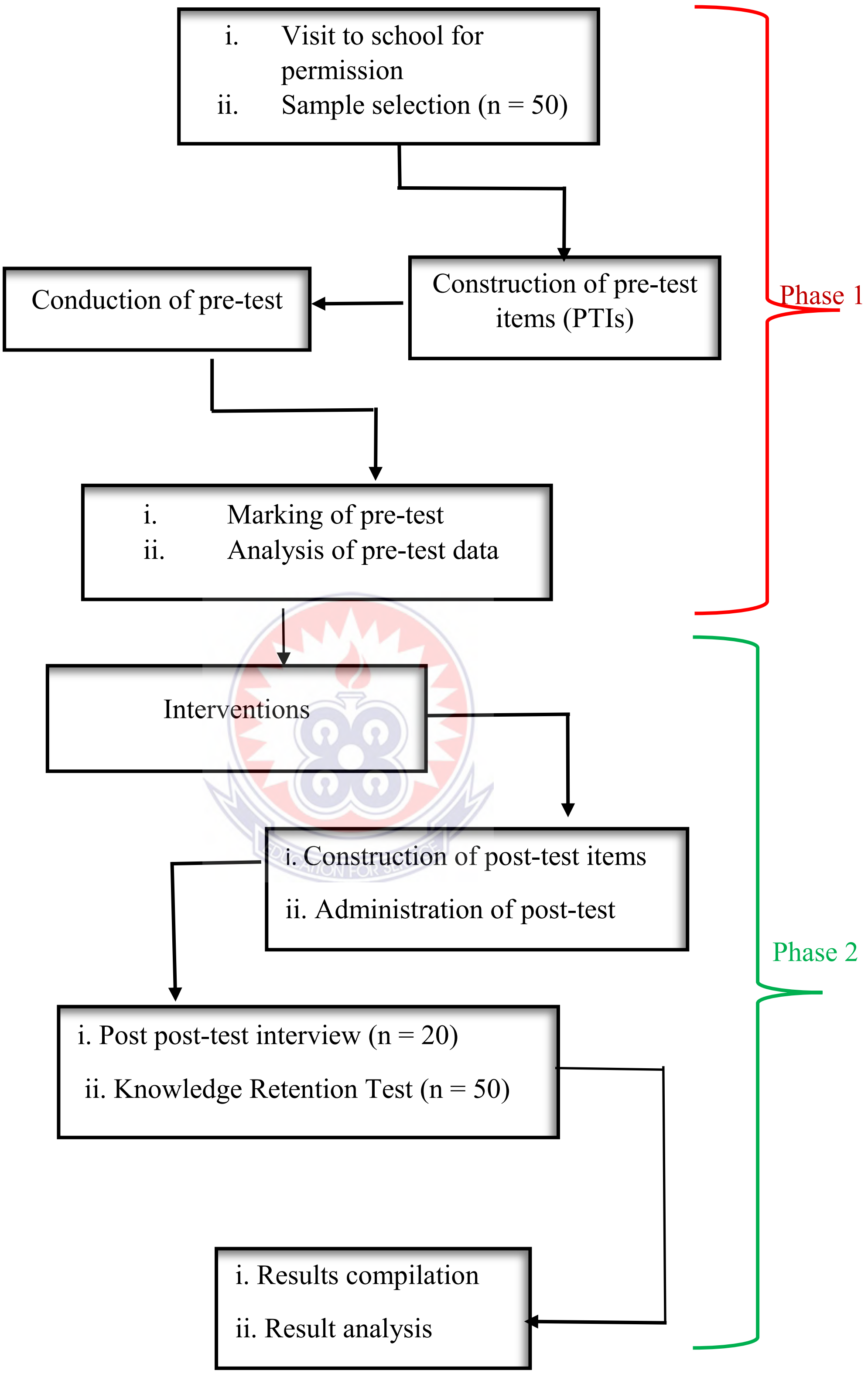

Figure 6: An overview of the data collection and analysis procedure

3.10 Data Collection Procedure

The researcher applied for and was given an introduction letter from the Department of Integrated Science Education of the University of Education, Winneba. The letter was presented to the assistant headmaster, adacemic of Nifa SHS to ask for permission and approval to conduct the research study. The Head of Department (HoD) for Science as well as the Biology master of the second-year science students were also talked to, for their permission and assistance. Participants were selected using stratified random sampling technique into the control and experimental groups. Each participant from each group was given a unique identification code. Pre-test items were constructed and conducted. This was followed by marking of the scripts and analysis of the results obtained. The analysis found the groups to be at parity and therefore the intervention was carried out. Before the intervention, the control and experimental group participants were given orientation on different occasions about the importance of the research study by the researcher. They were also instructed not to disclose any information to any other participant outside his or her own group. This is to prevent any form of interaction between the experimental group and the control group participants. Construction and administration of the post-test (Conceptual Understanding Test, CUT) and Knowledge Retention Test (KRT) were carried out after the intervention within an interval of four (4) weeks. Results of the CUT, KRT, interview and observation were finally compiled and analysed. Figure 6 summarises the data collection procedure used in this research study.

3.11 Intervention

The implementation of the intervention lasted five (5) weeks with three 2 hours lessons per week. Before the intervention, photosynthesis and mineral nutrition pre-test was conducted to both the control and experimental groups as suggested by Creswell (2012) to determine parity of the groups. After the pre-test administration, teaching was executed in the same manner in the two groups using the conventional method of teaching. Throughout this process, the marker board, textbooks and teacher-made notes were used as participants in both groups take down note. Research participants in the control group were required to re-examine the lessons making use of question-answer approach and allocating tasks in the textbook as pieces of assignments. On the other hand, MIA in the forms of educational videos, scientific games, and practical activities were used to guide and facilitate the review, reinforcement, motivate and assessment of participants in the experimental group‟s lesson materials.

Educational videos on photosynthesis and mineral nutrition prepared by Centre for National Distance Learning and Open Schooling (formerly PSI – Distance Learning) were used. These CDs/DVDs are available in some SHSs. These videos were watched during the evening prep times for convenient sake. The Content of the videos reflected that of the SHS Biology syllabus. The videos were watched before and after each sub-topic of the main topic under consideration were taught.

Five different scientific games – Word Search, Categories, Annotated Diagrams, Interactivity List and Dialog – about different sub-topics of photosynthesis and mineral nutrition unit were developed using the Xerte Toolkits software. These scientific games were developed by the researcher based on some assistance, suggestions and recommendations from experts and other biology teachers. In developing the games, specific attention was given to the objectives and the content of the topic under consideration. Much attention was also paid to the age of the students as well as the appropriateness of the games to their academic and cognitive level of development (Selvi & Çoşan, 2018). A game relevant to a particular sub-topic is played before and after the lesson to give a general picture of the sub-topic to be learnt and to reinforce what has already been learnt respectively.

One practical work per week was performed for the five weeks of the intervention period according to the arrangement of the topics outlined in the SHS Biology GAST by Ali, Nyavor and Seddoh (2006) as follows:

i. Testing for starch in a leaf
ii. To show that oxygen is evolved by a plant as a result of photosynthesis
iii. Investigating the need for carbon (IV) oxide in the formation of starch in a plant
iv. Investigating the need for sunlight in the formation of starch in a plant
v. Investigating the need for chlorophyll in the formation of starch in a plant

The practical proceeded in three stages namely:

i. Explaining the procedures involved as powerpointed to the participants by the teacher
ii. Teacher demonstration by following the procedures
iii. Participants activities in their groups.

3.12 Data Analysis Procedure

Data were analysed with the help of Microsoft Excel Version 2016. The results of the analysis were presented in tables with percentages calculated for easy understanding, interpretation and drawing of conclusion.

3.13 Ethical considerations

Permission to conduct the research study was sought from the school administration of Nifa Senior High, the HoD of the Science Department, and individual teachers of the department. The purpose of the research and the strategic procedures involved are explained to the protocols stated above as well as the prospective participants. Confidentiality of the participants and the scores obtained from the test was kept and respected.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

In chapter four, data obtained were analysed and presented in tabular forms for easy reading and comprehension in connection with the research questions as well as the hypothesis as outlined in the first chapter of this research work. The analyses were categorized into quantitative results and qualitative results with thorough discussion of the findings.

4.1 Bio Data Information of the Participants

The bio data of the respondents is presented in Table 6.

Table 6: Bio data of participants

Gender	24 males and 26 females
Age range	16 – 18 years
Educational level	Second cycle
Religion	All Christians
Nationality	All Ghanaians

4.2 Discussion of Quantitative Results

Research Question 1

To what extent is the pre-test of the control group significantly different from the pre-test of the experimental group before the intervention using MIA? To answer this research question, the raw pass and fail percentages of the respondents were calculated and tabulated as illustrated in Table 7, followed by the calculations involving the student"s t-test for the mean scores, standard deviations and the p-value for the two groups as outlined in Table 8.

Null Hypothesis

There is no statistically significant difference in the pre-test performance between the control group and the experimental group.

4.2.1 Discussion of Research Question One

Analysis of research question one based on the raw scores of the respondents in the control and experimental groups students" pre-test scores are shown in Table 7.

Out of a sample size of 25 respondents per each group, 13 and 12 respondents constituting the control group pass and fail the pre-test respectively representing 52% and 48% as shown in Table 6. For the experimental group, 14 and 11 respondents pass and fail the pre-test respectively, representing 56% and 44% as presented in Table 7. This performance of which more than 40% of the students failed the exams agreed with Ameyaw-Akumfi and Enstua-Mensah (2004), who argued that any programme of science education that fails more than 40% of its candidates should be re-looked at; because no nation can develop its science and technology base efficiently and effectively if more than 40% of students fail to comprehend basic concepts and terminologies in the subject.

Table 7: Raw scores of respondents in the pre-test

Group	Condition	Number	Percentage
Experimental	Pass	14	56%
	Fail	11	44%
Control	Pass	13	52%
	Fail	12	48%

No statistically significant difference was found between the control and the experimental groups in terms of students pre-test scores [$t_{(48)}$= -1.194, p>.05]. This finding agrees with Creswell (2012), who argues that in educational experimental research pre-test is relevant in order to ensure parity of the groups so that any significant observation made latter will be attributed as the effect of the intervention carried out.

Table 8: Independent samples t-test results of control and experimental groups' pre-test scores.

Group	N	$\bar{X}$	SD	Df	t stat	p_{val}
Control	25	20.68	2.51	48	-1.194	.238
Experimental	25	19.84	2.46			

***Significant at p<0.05**

Research Question 2

To what extent is the post-test and Knowledge Retention Test of the control group significantly different from that of the experimental group after exposing the experimental group to MIA?

Again, to answer this question, the raw pass and fail percentages of the respondents were calculated and tabulated as illustrated in Table 9. This was followed by the calculations involving the student"s t-test for the mean scores, standard deviations and the p-value for the two groups as outlined in Tables 10 and 11 for CUT and KRT tests score respectively.

Null Hypothesis

There is no statistically significant difference in the performance of students taught using MIA and those taught using traditional method in the post-test and Knowledge Retention Test.

4.2.2 Discussion of Research Question Two

4.2.2.1 Discussion of Conceptual Understanding Test Result

From Table 9, it can be seen that 14 and 11 respondents forming the control group passed and failed the CUT respectively with the corresponding percentages being 56% and 44%. On the other hand, percentage pass in the experimental group has witness a significant increase, i.e. 23 and 2 respondents passed and failed the post-test respectively with the corresponding percentages being 92% and 8%.

Table 9: Raw scores of respondents in the post-test (CUT)

Group	Condition	Number	Percentage
Experimental	Pass	23	92%
	Fail	2	8%
Control	Pass	14	56%
	Fail	11	44%

The average score of the experimental group respondents ($\bar{x}$ = 64.52, SD = 9.30) was higher than that of the control group respondents ($\bar{x}$ = 52.36, SD = 13.95).

A statistically significant difference as indicated in Table 10 was realised between the experimental and control groups respondents‟ CUT scores [$t_{(48)} = 3.63$, $p<0.05$; d = 1.03] in that the p-value (0.0007) obtained was less than 0.05 significant level. The Cohen‟s d was computed to ascertain the effect size of the research and it was found to be 1.03. This value suggests a very large effect size (Cohen, 1988). Cohen d is the appropriate effect measure if the two groups have similar standard deviations and are of the same size.

Taking into consideration the experimental and control groups‟ mean marks of the pre-test and post-test as indicated in Tables 8 and 10 respectively, it can be realised that there is a difference between the means of the pre-test and post-test scores. The mean scores of each group saw an increment after the intervention. However, the increase was much higher in the experimental group‟s post-test which was instructed using the MIA – educational videos, practical activities and scientific games. This result agrees with Muraina, Adegboye, Adegoke and Oligido (2019) who found the use of multimodal teaching approach to have favoured students achievement and self-esteem in programming.

It is believed that the significant increase in the number of respondents in the experimental group who passed the post-test successfully can be attributed to the use of MIA in the instruction which produced a learning system characterised by participation and motivation. This instructional strategy increased participants‟ interests and self-confidence in learning the content taught and helped boosted their concentration and team work in the course of teaching and learning. Conceptual understanding usually occurs, according to literature reviewed, through the participants" engagement with the opportunities provided by the learning environment and the experiences learners are exposed to. This guides respondents in creating a cognitive image of these experiences and opportunities based on the peculiar features of the experiences.

The outcome of the study can also be credited to the fact that MIA facilitated effective revision as students have the opportunity to watch educational videos and play scientific games as many times as possible notwithstanding their academic performance; thus, all learners of high and low academic performance can get involved in these activities. Many studies have advocated the use of MIA in instruction as it provides engaging environment for learning. Selvi and Çoşan (2018) recommended the use of educational games in teaching after they find it effective in teaching Kingdoms of Living Things. Ganapathy (2005) concluded that "multimodal approaches promote students" engagement in the teaching and learning and that students" perception is described as highly engaging, self-directed, and learner-centered and promotes meaning-making with minimal guidance from the teachers". Muraina, Adegboye, Adegoke and Ologido (2019) showed that using multimodality for instructional supports provided teachers the opportunities to help learners gain nuanced understanding, effectively demonstrate what they learned and unearth an intellectual haven.

Table 10: Unpaired samples t-test outcomes in terms of control and experimental group respondents' post-test CUT scores

Group	N	$\bar{X}$	SD	Df	t stat	p_{val}
Control	25	52.36	13.95	48	3.63	0.0007
Experimental	25	64.52	9.30			

***Significant at p<0.05**

4.2.2.2 Discussion of Knowledge Retention Test Result

The mean mark of the experimental group respondents ($\bar{X}$ = 39.92, SD = 5.77) for KRT was much higher as compared to that of the control group respondents ($\bar{X}$ = 34.80, SD = 7.35). A statistically significant difference as observed in Table 11 was realised between the experimental group and control group respondents knowledge retention assessment marks [$t_{(48)}$=2.74, p<0.05; d=0.77]. Also, Cohen‟s d was computed to ascertain the effect size of the parameters which was found to be 0.77. This value shows a large effect size (Cohen, 1988).

It has been demonstrated that the use of MIA to teach photosynthesis and mineral nutrition unit of the Biology syllabus played a significant role to the conceptual understanding of the respondents. Also, the methodology was fruitful in conserving the retention of respondents‟ understanding. Further, it can be mentioned that the activities and questions accommodated in the MIA accelerated the learning of the participants by triggering the numerous intellectual operations and escalated the retention of knowledge and understanding. This confirms a research study conducted by Corporation for Public Broadcasting in 2004 that gathered that „„„children‟s viewing of educational television has been shown to support significant and lasting learning gains‟‟‟ and that „„„a positive relationship has been found between childhood viewing of educational television and cognitive performance at both preschooler and college levels"". Also, as stated in the literature review, researches conducted from the early 1970s has been summarized by Fisch (2005) which gives robust evidence for the „„educational effectiveness of *Sesame Street*"". Among early grade students, habitual *Sesame Street* viewers exhibited remarkably substantial growth in a diversity of academic prowess and in school preparedness. These results have lasting positive benefits for learners, as demonstrated by a „„recollect""research that establish learners of high school who viewed Sasame Street and some other educational television and video as early grade students had better grades and manifested excellent pedagogy of self-esteem than peers who did not viewed instructional TV (Anderson et al., 1987, cited in Cruse, 2007).

Table 11: Independent samples t-test outcomes in terms of control and experimental group respondents' retention assessment scores

Group	N	$\bar{X}$	SD	Df	t stat	P_{val}
Control	25	34.80	7.35	48	2.74	0.009
Experimental	25	39.92	5.77			

Research Question 3

To what extent is the performance of male students different from female students who are taught using the MIA?

In response to research questions 3, calculations involving the student"s t-test was employed to investigate the significance of the mean differences of the conceptual understanding post-test due to gender variables as outlined in Tables 12.

Null Hypothesis

There is no statistically significant difference in the performance of male and female students taught by using the MIA.

4.2.3 Discussion of Research Question Three

The outcome as indicated in Table 12 points that there is no statistically significant difference in the respondents‟ conceptual understanding ascribed to the gender variable [$t_{(48)}=0.42$, $p>0.05$] who were taught using the same methodology. By this result, the researcher wishes to state that the use of MIA in this study aims at achieving specific content knowledge to all students at a specific level despite the gender of the student.

The outcome can also be attributed to the presumption that MIA inspired and motivated both male and female students to study. The methodology attracted their attention and boosted their motivation equitably as learners. Besides, the outcome can be credited to the parallelism of the learning conditions that male and female respondents were exposed to, which contributed essentially to the equivalence of the conceptual understanding. This research result agrees with other research findings that both male and female students gained equally when exposed to the same intervention under the same conditions with regard to content learning (Al-Tarawneh, 2016; Klisch, Miller, Beier & Wang, 2012).

Table 12: Comparison of Boys and Girls Performance Taught by MIA

Groups	N	$\bar{x}$	SD	Df	t stat	p_{val}
Boys	10	65.2	9.95	18	0.83	0.42
Girls	10	61.3	10.31			

*Significant at $p<0.05$

4.3 Discussion of Qualitative Result

Objective Number 4

What are the perceptions of learners on the use of MIA in teaching and learning photosynthesis and mineral nutrition unit in the Biology syllabus?

4.3.1 Discussion of Students' Perceptions on the use of MIA in Learning

The respondents‟ perceptions on research question 3 were analysed according to the codes driven and tabulated in Table 13.

From Table 13, majority of the respondents (f=22), representing 88% of the sample size indicated that using MIA in the teaching and learning process facilitated their involvement in the lesson, hence promoted their learning as stated by (f=20), representing 80% of the total sample size. Another group of respondents (f=19), in percentage term of 76% argued that their interest was aroused and sustained throughout the period of the intervention, culminating in higher retention of material learnt as expressed by the respondents (f=19), making 76%. This revelation aligns with Cruse (2007), who explains that „„among frequent users – teachers who report using TV and video for two or more hours per week – two-thirds find that students learn more when TV or video is used, and close to 70% find that student motivation increases. More than half of frequent users also find that students use new terminologies as a result of video use‟‟.

Furthermore, 68% of the respondents stated that MIA helped them nurtured their self-confidence and facilitated their understanding of new concepts, while 64% argued that the methodology helped them developed new ideas for learning and that they are ever ready to learn more with MIA as stated by 56% of the respondents. Besides, some respondents, representing 52%, 52% and 44% indicated that MIA enabled them to revised, improved their motivation and made them like the lessons respectively. This result was also revealed by CPB (2004) who indicated that video and television for classroom instruction enhance learner motivation and enthusiasm.

Some specific views expressed by some of the respondents on the use of MIA are outlined below:

> *EF_2S1: MIA assisted us to study the content of the topic with ease. Everything we learnt is still new in my mind and I do not think I will forget all that I learnt. Also he/she content of the MIA is very clear and simple to our understanding.*

In the same vein, EF_2S6 indicated that though this is the first time they are learning using MIA, the method is helping them to focus on the lessons because you cannot be watching an interesting educational video and be thinking of something outside the classroom situation. He or she expressed the opinion that the methodology is appropriate to their level of learning and that it often prevents any form of distraction.

> *EF_2S6: The methodology always catches our attention in class and actually caused us to like the subject. We were able to express our ideas better. We now come to understand that Biology is an interesting subject. We can now learn other topics in the Biology with the new ideas we developed without much difficulties.*

For EF_2S11, he or she stated that the use of MIA motivated them to the level that they wish the methodology is replicated in teaching other science subjects – Chemistry, Physics and Elective Mathematics.

> *EF_2S11: I wish that other science teachers also adopt the use of MIA in teaching us the other science subjects. We feel motivated anytime it is time for Biology lesson. I was able to identified my mistakes and corrected them.*

For their part, EF_2H2 and EF_2H5 indicated that the use of MIA in learning promoted their interest in the lessons and assisted them in effective team work and collaboration besides improving their understanding and retention of the subject matter.

> *EF_2H2: We were able to work together in my group during the practical lessons. Everybody was making effective contributions and my personal collaboration with my group members was encouraging. In fact, MIA fostered my self-confidence and brought me at par with my colleagues.*
>
> *EF_2H5: We developed more interest in learning the Biology topic and understood the content more easily. There is no room for playing. We were all participating fully in the lesson and that is why we can still remember all that we were taught. I hope this methodology of teaching and learning will continue.*

Table 13: Respondents' Perceptions on the use of MIA in learning

Respondents" Perceptions	Frequency	Percentage
MIA promoted my engagement in the lessons	22	88%
MIA made me learn more	20	80%
MIA boosted and sustained interest to learn	19	76%
MIA improved my retention of concepts	19	76%
My self-confidence was nurtured	17	68%
MIA facilitated my understanding of concepts	17	68%
I developed new experiences for learning	16	64%
MIA encouraged team work	14	56%
I am ever ready to learn with MIA	14	56%
MIA enabled me revise the topic	13	52%
My motivation was improved	13	52%
I like the lesson	11	44%
MIA developed my boldness	9	36%
I realized and worked on my mistakes	7	25%
MIA provided no room for playing	6	24%
No laziness set in	6	24%
	4	16%

The respondents were asked again *"In general, how will you rate your views for learning with MIA on a scale of „excellent", „very good", „good", „satisfactory", „ poor" or „very poor"?* Participants" responses to the question were analysed and the results presented in Table 14.

4.3.2 Discussion of Students' Rating for reasons for Using MIA in Teaching and Learning

As Table 14 indicates, 20 students representing 80% expressed the view that MIA promoted their participation in the lesson and therefore rated the methodology as excellent for teaching and learning Biology. This finding supports Computer Technology Research, CTR reports that students retain as much as 80% of what they see, hear and do simultaneously (Timothy, 1998).

Closely followed by this is another group of respondents (f=19) representing 76% of the sample size who also expressed the view that the use of MIA is excellent not only is sustaining interest in the learning of photosynthesis and mineral nutrition topic of the Biology but also facilitated their understanding of the topic. To this, Mayer (2001) maintains that while viewing may be considered secondary, it can, at the same time, be an effective tool for excellent intellectual activity required for active learning. He contends that „„„well-structured multimodal instructional information can elevate active intellectual processing in learners, even when they (learners) appear inactive.

Furthermore, 72% and 64% of the respondents rated the use of MIA as excellent and very good for making learning easier and promoted retention of knowledge respectively. Some other views expressed by some of the respondents on the second question are outlined as follows: MIA motivated us to develop self-confidence. We can now learn on our own by sharing ideas, said EF_2S2. "Going back to the old methods of teaching and learning Biology will be very boring and will make us inactive in class again". He/she said this when realized that the intervention period is over.

> *EF_2S13: Learning with MIA provides a lot of assistance and makes the lessons easier to understand. It affords me the opportunity to evaluate my learning progress as I participated fully in the lessons. I worked hard on my shortcomings by engaging with my colleagues in sharing ideas. My interest in learning the topic – Photosynthesis and Mineral Nutrition – has advanced. I did my best to score better marks in the games with my group members.*

> *EF_2H17: I want to state that MIA helped us learned a lot within this short period. We were able to follow the procedure provided to perform all the experiments during the practical lessons. I developed interest in watching the videos. It was very clear to our understanding. In fact, I can explain all that we were taught because I can remember all.*

> *EF_2S18: I developed self-confidence in whatever I do now. I can now ask questions in class unlike the previous. I assessed my learning and is better these days. We were motivated especially with the practical activities. The videos were also to our level and very entertaining. We were all eager to learn. It was an interesting experience.*

Judging from all these views expressed by the respondents, it was evident that the use of MIA for teaching and learning the topic under consideration positively imparted their studies. This agrees with other results of researches conducted by different researchers at different places, including (Muraina, Adegboye, Adegoke & Ologido, 2019; Selvi & Çoşan, 2018; Al-Tarawneh, 2016).

Table 14: Students' rating of the various reasons for using MIA in teaching and learning

Respondents' Views	Frequency	Rate
MIA promoted participation	20	Excellent
MIA sustained our interest in learning the topic	19	Excellent
MIA facilitated our understanding	19	Excellent
Learning was easier with MIA	18	Excellent
MIA provided retention of knowledge	16	Very Good
I developed self-confidence	16	Very Good
Motivation was improved	15	Very Good
Team work was encouraged	14	Good
I developed new experiences for learning	12	Good/Satisfactory
I had the opportunity to review the lessons	10	Good/Satisfactory
I enjoyed the lessons	9	Good/Satisfactory
I saw my mistakes and corrected them	7	Satisfactory

Finally, the respondents were asked the question *"State some of your views why you think Biology students should be taught using MIA"*. Table 15 outlines some of the views expressed by the students.

4.3.3 Discussions of Views Expressed by Students About the Importance of MIA in Teaching and Learning

From Table 15, it can be seen that majority of the respondents, (f=21), representing 84% stated the that MIA should be used in teaching and learning Biology because it stimulates active participation in the lesson. The main focus of every method of teaching is to enhance students‟ participation and to make the lesson real and concrete. Some respondents, (f=18), representing 72% and (f=15), representing 60% are of the views that MIA as a means of learning prevents total distraction from the lesson and also promotes team work and collaboration among learners respectively. Other respondents (52%) outlined the views that MIA helped increased their interest in the learning process as well as facilitated the learning itself. This result is in concordance with Lirola"s 2014 finding as cited in Lirola (2016) that understanding the classroom setting as a multimodal system suggests that the various channels of communication used to convey message contribute effectively so that the teaching and learning process is dynamic and creative, which promotes students" learning process. Some specific reasons provided by EF_2S9, EF_2S15 and EF_2H1 are outlined as follows:

> *EF_2S9: The MIA method of teaching and learning Biology promotes attendance in class and takes away laziness in us. Everybody was ready to learn. My group always wants to score higher marks in the games. The method was also helpful in that we had the opportunity to watch the videos severally.*
>
> *EF_2S15: The method made me feel confident in whatever answer I want to give in class. I have no doubt that my answers I give in class would be correct. I can still do better in the Biology subject because MIA give clear guidance in whatever we do. I recommend the use of MIA in teaching and learning because it gives me the hope and motivation that I would do better.*
>
> *EF_2H1: He or she stated that MIA encouraged interpersonal relationship between teacher-student on one hand and student-student relationship on the other hand. We are free to learn from each other and we share ideas from time to time. We play the games together, watch the videos together and we do everything together. MIA is actually helpful in understanding ourselves. I developed interest in all the lessons.*

This revelation by EF_2H1 agrees with the words of Spivey (1985) that effective interpersonal relationships between teacher and student are vital components of the educational system if the former and the latter are to have enough time to teach and to learn respectively. He further contends that cordial working relationships between teacher and student is the result of good classroom atmosphere (p. 6).

EF_2S2, EF_2S4, EF2S7, EF_2S12, EF_2H4 and EF_2H6 expressed the happiness and joy for being part of this exercise. They proposed that this methodology be extended to colleagues who were unfortunate to be included in this research work. They further posited that the MIA is helpful and effective in comparison to other methods of instruction known to them. They contended that the methodology instilled in them a repertoire of learning skills and strategies.

All these views expressed by the respondents concerning the use of MIA in teaching and learning Biology are mainly positive as acknowledged from the above explanations. The respondents realized that using the MIA was effective in promoting participation, encouraging team work and collaboration and facilitating retention of knowledge, just to mention a few. These favourable characteristic features of MIA, in no doubt, contributed significantly to the intellectual learning by bestowing not only to the development of affective domain of students but also their psychomotor characteristics.

Table 15: Students' views on the use of MIA for Teaching and Learning

Respondents' Views	Frequency	Percentage
MIA stimulates active participation	21	84%
MIA prevents distraction	18	72%
It promotes team work and collaboration	15	60%
MIA increases interest in learning	14	56%
It provides guidance in learning	13	52%
It encourages revision	11	44%
MIA is effective for motivation	9	36%
It nurtures self-confidence	9	36%
It advances knowledge retention	7	28%
MIA elevates group discussion	7	28%
MIA prevents laziness	5	20%
It encourages interpersonal relationships	4	16%
It promotes attendance in class	2	8%

4.4 Discussion Relating to Observation

During the intervention period, the respondents‟ behaviours, attitudes and reactions were critically observed. The results of the observation were noted in the observation log and presented below.

Educational videos on photosynthesis and mineral nutrition were watched during the evening prep time because normal teaching hours will not be convenient. Students developed much interest in the videos in such a way that they do arrived at the venue earlier than the scheduled time. They usually rushed for the front seats.

In the course of watching the educational videos, respondents were all quiet and well-focused. They were almost seen taking down notes. There was no form of distraction and no form of communication was observed. No noise was heard in the classroom and the activity proceeded as planned. The participants watched the videos with rapt attention. At the end of each viewing, students discussed their notes and findings among themselves in order to share ideas. They also asked questions for teacher‟s explanation on areas that seem difficult to them. Some respondents expressed the concern that the videos should have lasted a little bit longer. Students were able to answer few evaluation questions from the teacher immediately after watching the video. For example, *outline any three structural adaptations of the leaf of a plant for photosynthesis.* Students‟ responses to this question include "the leaf has a flat shape, providing a large surface area to allow maximum absorption of sunlight and carbon (IV) oxide" and "the numerous networks of veins supply the photosynthetic cells with water and minerals and removes the products of photosynthesis". They asked for permission to watch the videos again, of which permission was granted.

During the games, most respondents understood and obeyed the rules of the games. Initially, some were unable to finish within the stipulated time but as the games progressed, they were able to. There were interesting competitions among the various groups. Some students were quiet at the commencement of the games, but their interest aroused as the games proceeded and winner were being mentioned. The respondents created their own strategies and techniques in order to finish early and be awarded higher marks.

The Wordsearch Game, in particular, contains all the technical terms in the topic being studied and was therefore the last game to be played. The game created very exciting moments as most respondents indicated that the games were very entertaining and catches their attention. It was observed that most students were very focused as stipulated time to finish ran fast. Some students were prompted by their colleagues whenever they make a mistake for early remedy. It was also observed that competition between groups heightened upon receiving the message that the winner will be given some recognition in class the following day. The respondents experienced a well-organised and well-motivated learning environment culminating in their collaborative team work and effective working relationships among individuals and groups.

Practical lessons were held once in a week according to the topics outlined in the SHS Biology Syllabus/GAST to cover all the five weeks of the intervention period. During each practical session, respondents were very attentive as the instructor powerpointed and explained the procedures involved to them. Respondents often asked questions on some procedures that seemed unclear to them. During teacher demonstrations that proceeded their group activities, students were very focused and developed keen interest as the processes unfolded. Despite the PowerPoint projected on the markerboard, the students were still seen jotting down supplementary notes in their notebooks. During their first trial activity in their usual groups, it was observed that the respondents were extremely careful in handling the apparatus and the reagents, perhaps in order not to destroy any apparatus or miss any step of the activity. They interestingly followed and obeyed all laboratory rules in the course of the practical work. They expressed joy and happiness after going through the steps successfully and the end results were achieved.

Throughout the period of intervention, the students actively participated in all the lessons and activities. Besides, the students exhibited the spirit of collaboration and communicated brilliantly with their mates. They were actually part and parcel of each session of teaching and learning. Punctuality and regularity were held in high esteem.

It was clear that the operationalisation of the MIA enhances effective teaching and learning. It stumps up the development of study skills and competencies in the respondents and that the employment of the methodology promoted participants" influence in the teaching and learning activities. This is because participants have to shoulder an active role as they learn. The use of various multimodal techniques – educational videos, practical activities and scientific games – aided participants" creativity owing to the fact that they made intelligent effort to the combination of different learning strategies to facilitate classroom interactions among themselves. No wonder the performance of the experimental group is significantly different from their corresponding control group in both the CUT and KRT.

Again, creativity was enhanced because in addition to group interactions and discussions among participants, they also have the opportunity to watch educational videos and play scientific games, all on photosynthesis and mineral nutrition. From my observation, I can conclude that the importance of using multimodal technique in teaching and learning Biology include, but not limited to the following:

1. that the methodology motivated respondents both intrinsically and extrinsically, resulting in active participation in the lessons.
2. that the methodology influenced students‟ creativity by placing them at the centre of the teaching and learning process with the researcher acting as a facilitator because all the necessary facilities – videos, games, practical materials etc - needed for self-directional learning have been put in place. This agrees with Abell and Pizzini (1992) that the science educator‟s role includes being a mentor, a person who facilitates learners‟ deep comprehension, and also, one who promotes the acquisition of children‟s in-depth thinking and creativity in problems analysis and solving procedures.
3. that the technique enabled respondents to experienced concrete learning because of the resources that are readily available to the students. This helped prevented abstract thinking.
4. that the methodology facilitated learners‟ understanding of basic concepts and principles of the topic under consideration. For example, the concept *"structural adaptations of the leaf for photosynthesis"* was discussed by physically examining different broad leaves types during the lesson.
5. that the technique enabled retention of knowledge. This is true as seen in higher performance in favour of the experimental group in the KRT.

On a whole, it can be stated that multimodal technique supported the teaching and learning of Biology and established a direct and a strong interconnection between the discipline and real-life issues.

However, few cases of absenteeism and lateness to class were observed.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

5.0. Overview

In chapter five, a summary of the research findings was provided. These were employed in drawing conclusions in terms of research questions and hypotheses. Finally, recommendations and suggestions for further research were given to broaden the horizon, and to serve as a knowledge base to other researchers and any other person(s) or an organization who may find this material useful in conducting further researches.

5.1. Summary

The purpose for this research study comprehensively focused on how best students" conceptual understanding and knowledge retention could be enhanced using MIA in the teaching and learning processes of Photosynthesis and Mineral Nutrition in Plants, a topic in the SHS Biology syllabus. The research was concentrated around four research objectives and four research questions. To achieve these objectives and answer the research questions, I conducted a quasi-experimental research in Nifa SHS. In doing this, data was collected from 50 second year science students using self-designed Conceptual Understanding Test, Knowledge Retention Test, interview and observation protocols for purposes of data triangulation.

I conducted a pre-test which was followed by five weeks of intervention, and then a post-test. During the intervention period, participants observation was carried out "for supporting evidence and clarification" (Gablinske, 2014). Interview and delayed post-test were conducted immediately and eight weeks after the administration of the post-test respectively.

5.2 Conclusions

This research work investigated the impart of MIA in enhancing conceptual understanding and knowledge retention of second year science students of Nifa SHS. The outcomes indicated a statistically significant difference in favour of the experimental group participants for both the Conceptual Understanding Test and Knowledge Retention Test. These results align with suggestions put forward that the employment of multifaceted teaching strategies by all teachers is needed to meet the various learning styles in the classroom setting (Maduadum, 1994; Akubuilo, 2004; Achor, 2008).

The research also revealed that the use of MIA increased respondents conceptual understanding, and acted as an excellent device for facilitating the retention of new intellectual knowledge. Similarly, Marchetti and Cullen (2016) in their article titled "a multimodal approach in the classroom for creative teaching and learning" found out that "engaging in course content requires strategies of communication that focus and maintain attention" ……"and as the research results demonstrate, the students responded favourably to multimodal input".

The experimental group respondents remarked on the use of MIA in the course of teaching and learning. Their remarks and explanations indicated that the use of MIA in the lesson assisted respondents to study and promoted particular expertise, in addition to increase in their intellectual accomplishment and knowledge retention.

Some of respondents" remarks on the importance of MIA in the teaching and learning include:

1. MIA promoted active participation in the lessons
2. MIA promoted effective team work and collaboration
3. It facilitated our interest in the lesson
4. Our motivation was higher in the teaching and learning process

From these, I found out that MIA is an exceedingly stimulating strategy to teaching and learning that embraces factors of individualistic and group competitiveness.

5.3 Recommendations

On the basis of results produced from this research work, the researcher suggests and recommends that:

1. Science teachers should adopt MIA in teaching in addition to other methods of instruction.
2. Organising educational workshops and seminars for science teachers to enhance their skills and competencies in designing and using MIA in science lessons.
3. Teacher training institutions are encouraged to include frameworks of theories of designing MIA in initial teacher preparation programmes.
4. More similar researches be conducted on using MIA in teaching in other schools as well as other subject areas.

5.4 suggestions for Further Research

In order to have more insight into the impact of multimodal instructional approach on students" conceptual understanding and knowledge retention, the researcher suggests the following, that:

a. this research study may be replicated in other Metropolitan, Municipal and Districts throughout the country to ascertain its effectiveness and usefulness.
b. the duration for the intervention be prolonged to cover a whole academic year, so that future study will cover about five different units in the SHS Biology syllabus.
c. three different experimental groups at the same academic level be used in the future research study. The first group be taught using project-based learning while the second and third groups be taught using concept mapping and multimodal instructional approach respectively.

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APPENDICES

Appendix A: List of Abbreviations

ACSA	Association of California School Administrators
CLs	Cognitive Loads
CLT	Cognitive Load Theory
CoA	Commonwealth of Australia
CPB	Corporation for Public Broadcasting
CPD	Continuous Professional Development
CRDD	Curriculum Research and Development Division
CTML	Cognitive Theory of Multimodal Learning
CTR	Computer Technology Research
CUT	Conceptual Understanding Test
DfEE	Department for Education and Employment
ESL	English as a Second Language
FNG	Federal Nigeria Government
GAST	Ghana Association of Science Teachers
GES	Ghana Education Service
HoD	Head of Department
ICT	Information and Communication Technology
IT	Information Technology
IWB	International White Board
KG	Kindergarten
KRT	Knowledge Retention Test
MESTI	Ministry of Environment, Science, Technology and Innovation
MIA	Multimodal Instructional Approach
MIAI	Multimodal Instructional Approach Instrument
MOE	Ministry of Education
NCLB	No Child Left Behind
NLG	The New London Group

NRC	National Research Council
NTC	National Teaching Council
NTECF	National Teacher Education Curriculum Framework
PCK	Pedagogical Content Knowledge
QCA	Qualifications and Curriculum Authority
SADC	Southern African Development Community
SBL	The Society of Biology, London
SHS	Senior High School
SPSS	Statistical Packages for the Social Sciences
STI	Science, Technology and Innovation
TPCK	Technological Pedagogical Content Knowledge
TV	Television
WGBH	Great Blue Hill

Appendix B: Table of Specification for the pre-test items

	Behaviours				
Content Area	Knowledge	Comprehension	Application	Evaluation	Total
The process of photosynthesis	3	3	1		7
Structural adaptations of the leaf for photosynthesis		2		1	3
Biochemical nature of photosynthesis	3	3	1		7
The effects of macronutrients and micronutrients	1	1	3		5
Factors affecting the rate of photosynthesis	1		1	1	3
Total	8	9	6	2	25

Appendix C: Sample of pre-test items

PRE – TEST ITEMS

Instructions: Answer all the questions on the question paper

Time Allowed: 1 Hr 10 mins

Student's identification No: ……………………………………………………

1. By which one of the following processes does carbon (IV) oxide pass through leaf stomata?
   a. Osmosis b. diffusion c. absorption d. transpiration
2. Which one of the following most appropriately completes the equation written below?
   Carbon (IV) oxide + water → glucose + …….
   a. Starch b. energy c. oxygen d. sucrose
3. List the importance of each of the following macronutrients in plants
   a. NO_3^-
      ……………………………………………………………………………
      ……………………………………………………………………………
   b. Ca^{2+}
      ……………………………………………………………………………
      ……………………………………………………………………………
4. Evaluate how each of the following factors affects the rate of photosynthesis in plant
   a. Light intensity
      ……………………………………………………………………………
      ……………………………………………………………………………
      ……………………………………………………………………………
      ……………………………………………………………………………
   b. Temperature
      …………………………………………………………………………
      ……………………………………………………………………………
      ……………………………………………………………………………
   c.

5. The glucose produced during the process of photosynthesis has the chemical of

   a. $C_6H_{10}O_6$ b. $C_6H_{12}O_6$ c. $C_{12}H_6O_{12}$ d. $C_6H_{12}O_8$

6. State any three (3) adaptations of the leaf for photosynthesis

   i. …………………………………………………………………………
   …………………………………………………………………………

   ii. …………………………………………………………………………
   …………………………………………………………………………

   iii. …………………………………………………………………………
   …………………………………………………………………………

7. Which of the following foods is produced in the process of photosynthesis?

   a. Sucrose b. cellulose c. glucose d. fructose

8. The part of a leaf which is most photosynthetic is

   a. Palisade mesophyll b. pericycle tissue c. epidermal tissue d. vascular tissue

9. Provide the reason(s) for carrying out each of the following activities when testing for starch in a leaf by completing the table below.

Activity	Reason(s)
Leaf is placed in a beaker of boiling water	
Leaf is placed in a test tube containing alcohol	
Leaf is washed in a warm water	

10. What is the role of water in the process of photosynthesis?

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11. During heavy rains, leaching may lead to
    a. Vigorous plant growth b. loss of soil nutrients
    c. Migration of crop pests d. soil fertility
12. Nitrogen may be lost from the soil through
    a. Ammonification b. nitrification c. deamination
    d. denitrification
13. A farmer intercropped his maize plantation with beans in order
    a. Check soil erosion b. suppress the growth of weeds
    c. Add nitrates to the soil d. protects crops against grazers
14. The humus content of a soil can be renewed by application of
    a. Ammonia fertilizer b. compost c. NPK d. urea
15. What happens during the light-dependent stage of photosynthesis?
    a. NADP is reduced b. ADP is reduced c. FAD is reduced d. NAD is reduced
16. The oxygen given off during photosynthesis is obtained
    a. By the ionization of water b. By the combination of carbon dioxide and water
    c. By the breakdown of carbon dioxide d. From excess oxygen taken into the plant
17. Evaluate briefly the importance of the leaf to a plant

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18. Explain briefly how plants contribute to the reduction in climate change?

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19. Discuss the light reaction stage of photosynthesis

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20. State one benefit of photosynthesis

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21. Temperature and oxygen concentration are some of the factors that affect the rate of photosynthesis. **True/False**

22. The average rate of photosynthesis is higher in December than in June. **True/False**

23. Name the products of the light stage of photosynthesis that are useful in the dark stage.

……………………………………………………………………………………

24. Which cells of a plant are specialised for photosynthesis?

……………………………………………………………………………………

25. The main product of photosynthesis is an inorganic compound. **True/False**

Appendix D: Marking Scheme for pre-test

1. B **1 mark**
2. C **1 mark**
3. **Importance of NO_3^- and Ca^{2+}**
   a. NO_3^- involves in the synthesis of amino acids, proteins and other complex nitrogen compounds like chlorophyll **2 marks**
   b. Ca^{2+} involves in the building of cell wall **2 marks**
4. How light intensity and temperature affect the rate of photosynthesis
   a. Light intensity
   - the rate of photosynthesis increases linearly with increasing light intensity up to optimum light intensity
   - a further increase does not yield corresponding increase in photo.
   - it is a limiting factor for shaded plants
   - tall plant has an advantage over its short neighbor

   Any 2×1=2 marks

   b. Temperature
   - Photosynthesis during the dark stage is controlled by enzymes
   - Hence affected by temperature
   - An increase of 10ºC effectively doubles the activity of enzymes
   - The optimum temperature for photosynthesis in most temperate plants is 30ºC
   - Temperature above critical value (40ºC), the enzymes will be denatured
   - The rate then decreases rapidly and stops altogether

   Any 2×1=2 marks
5. B **1 mark**
6. **Three adaptations of the leaf for photosynthesis**
   - Has a broad, flat shape, giving a large surface area to allow maximum absorption of sunlight and CO_2
   - Its thin nature allows CO_2 to diffuse easily to mesophyll cells
   - Presence of numerous stomata ensure efficient exchange of gases

- Palisade mesophyll cells contain large number of chloroplasts for sunlight absorption
- Large air spaces between the spongy mesophyll cells allow gases to diffuse easily
- Numerous network of veins supplies photosynthetic cells with water and minerals and carries away the products of photosynthesis
- Arrangement of leaves along the stem in a regular pattern minimises overlapping and overshadowing. **Any 3×2 = 6 marks**

7. C **1 mark**
8. A **1 mark**
9. **Reasons for performing the following activities when testing for starch**
   - Placing leaf in a beaker of boiling water – to kill the cell and stop all chemical reaction
   - Placing the leaf in a test tube containing alcohol – to remove the chlorophyll from the leaf
   - Wash the leaf in water – to soften the leaf for iodine to penetrate through **3× 1 = 3 marks**
10. **Role of water on photosynthesis**
    - Water is splitted photochemically to produce H^+ and OH^-
    - The OH^- is converted back into water and O_2 as a by-product
    - The H^+ is accepted by NADP to form $NADPH_2$ **3×1 = 3 marks**
11. B **1 mark**
12. D **1 mark**
13. C **1 mark**
14. B **1 mark**
15. A **1 mark**
16. A **1 mark**
17. **Importance of the leaf to the plant**
    - Some leaves are involved in asexual reproduction
    - Produces food for the plant by photosynthesis
    - It is also involved in gaseous exchange
    - Absorbs light energy through the chlorophyll
    - Some leaves store food for the plant **Any 3×1 = 3 marks**

18. How plants contribute to the reduction in climate change

- By removing CO_2 from the air by the process of photosynthesis
- By storing carbon in the plants system and soil
- By releasing O_2 into the atmosphere **3×1 = 3 marks**

19. Light reaction of photosynthesis

- Occurs in the thylakoid membrane of the chloroplast
- Chlorophyll traps solar energy from sunlight
- Solar energy is converted into chemical energy
- The energy splits water molecules into H^+ and OH^-
- The OH^- is converted into water and O_2
- Water component is released into the atmosphere
- NADP is reduced to $NADPH_2$
- ATP is formed **Any 5×1=5 marks**

20. One benefit of photosynthesis

- Provides food for living organisms in the ecosystem
- Provides oxygen for animal respiration
- Purifies the air by removing CO_2 and replaces it with O_2
- Contributes to the reduction in greenhouse effect
- Reduces CO_2 content in the air
- Minimises climate change **Any 1×1 = 1 mark**

21. False **1 mark**

22. False **1 mark**

23. $NADPH_2$ and ATP **2×1 = 2 marks**

24. Palisade mesophyll cells **1 mark**

(correct spelling to score)

25. False **1 mark**

Maximum mark for pre-test is 50

Appendix E: Table of Specification for the post-test (CUT)

	Behaviours				
Content Area	Knowledge	Comprehension	Application	Evaluation	Total
The process of photosynthesis	3	2	2		7
Structural adaptations of the leaf for photosynthesis	1		1		2
Factors affecting the rate of photosynthesis	1	1	1		3
Biochemical nature of photosynthesis	4	6	1	1	12
The effects of macronutrients and micronutrients	4	2	2	1	9
Total	13	11	7	2	33

Appendix F: Sample of post-test (Conceptual Understanding Test) items

Conceptual Understand Test (Post-test) Items

Instruction: Answer all questions on the question paper

Time allowed: 1 hr 20 mins.

Respondent's Identification No: ………………………………..

1. Write a balanced chemical equation for photosynthesis

   ……………………………………………………………………………

2. Name the products of photosynthesis

   ……………………………………………………………………………

3. What conditions are necessary for photosynthesis to occur?

   ……………………………………………………………………………

4. The light stage of photosynthesis takes place in the ………………………… ………………………….. of the chloroplast

5. Write the first equation for photosynthesis

   ……………………………………………………………………………

6. Which of the following is a factor that affects the rate of photosynthesis?
   a. O_2 concentration b. CO_2 concentration c. H_2 concentration d. N_2 concentration

7. Write the full name for **RUBP**…………………………………………………

   ……………………………………………………………………………..

8. Name the first product of photosynthesis…………………………………?

9. The dark stage of photosynthesis is controlled by enzyme and therefore not affected by temperature **True/False**

10. Which of the stages of photosynthesis is also called the Calvin Cycle?

    ……………………………………………………………………………

11. Define photolysis……………………………….…………………………..

    ……………………………………………………………………………

12. What observation will you make when testing for starch in a leave?

    ……………………………………………………………………………

13. Which of the following is a hydrogen acceptor in photosynthesis?

    a. FAD b. NAD c. ADP d. NADP

14. What is the importance of RUBP in photosynthesis?

    a. It is a hydrogen acceptor b. it reacts with GP to form TP

    c. it is a source of phosphate ions d. it reacts with carbon (IV) oxide to form GP

15. A soil may lose its fertility through

    a. ridging b. shifting cultivation c. overcooling d. leaching

16. Name the reagent used when testing for starch in a leaf………………………..

17. When a variegated leaf is used as both the control and the experimental set-ups the researcher is investigating the necessity of

    a. Light for photosynthesis b. chlorophyll for photosynthesis

    c. carbon dioxide for photosynthesis d. water for photosynthesis

18. The light stage of photosynthesis involves

    a. Fixation of carbon dioxide b. the reduction of ribulose bisphosphate

    c. photolysis of water d. oxidation of NADPH to NADP

19. Explain brief the term photosynthesis

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20. The rate of photosynthesis in plant is high when

    a. Temperature is low b. carbon dioxide concentration is low

    c. Temperature is high d. water content of soil is low

21. An example of a micro-element required by plants is

    a. Boron   b. calcium   c. iron   d. nitrogen

22. Which of the following essential elements plays a role in the synthesis of chlorophyll molecule?

    a. Phosphorus   b. magnesium   c. calcium   d. sulphur

23. Chlorosis is plants can be reduced by applying

    a. Calcium and magnesium   b. potassium and phosphorus

    c. Sulphur and boron   d. nitrogen and iron

24. Micro elements are required in small quantities by plants because they

    a. do not actually need them   b. can be re-used by plants

    c. retard plant growth when in excess   d. can be synthesized by plant

25. The mineral salt important for cell wall formation is

    a. calcium   b. nitrogen   c. phosphorus   d. carbon

Use the list of essential nutrients below to answer questions 26 and 27

I. Molybdenum   II. Carbon   III. Nitrogen   IV. Copper

26. Which of the nutrients listed above are major nutrients?

    a. II and II only   b. I, and III only   c. II, III and IV only   d. II and III only

27. Which of them is/are needed by plants is minute quantities?

    a. I only   b. I, II and IV only   c. II and III only   d. I and IV only

28. Explain why the leaves of a seedling may be yellowish in appearance

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29. State the form(s) in which nitrogen is absorbed by plant

    ……………………………………………………………………………………

30. Excessive supply of macro nutrients to plants become toxic and hence may cause plants to die.   **True/False**

31. Describe a simple experiment performed by you or your teacher in the laboratory to demonstrate the need for chlorophyll in formation of starch in a plant.

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32. RUBP is a 6-carbon compound. **True/False**

33. Explain why you would advise a young boy not to destroy the leaves of a tomato plants in the backyard garden.

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Appendix G: Marking Scheme for the post-test (CUT)

1. $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ **[R=1, P=1, B=1 = 3 marks]**
2. Glucose and Oxygen **2×1= 2 marks**
3. Carbon (IV) oxide, water, chlorophyll and sunlight **4×1= 4 marks**
4. Thylakoid membrane **2 marks**
   (correct spellings to score)
5. $4H_2O \rightarrow 4H^+ + 4OH^-$ **[R=1, P=1 = 2 marks]**
6. B **2 marks**
7. Ribulose Bisphosphate **2 marks**
   (correct spellings to score)
8. Glycerate-3-phosphate/Phosphoglyceric Acid **2 marks**
   (Correct spellings to score)
9. False **2 marks**
10. The dark stage **2 marks**
11. Photolysis is the photochemical splitting of water molecules (1) into hydrogen ions and hydroxyl ions (1) **2 marks**
12. A blue-black colouration is formed **2 marks**
13. D **2 marks**
14. A **2 marks**
15. D **2 marks**
16. Iodine solution **2 marks**
17. A **2 marks**
18. B **2 marks**
19. Photosynthesis is the chemical process by which water and carbon (IV) oxide are combined (1) in the presence of sunlight and chlorophyll (1) to form glucose as the main product (1). Oxygen is a by-product of this process (1). Photosynthesis mainly takes place in autotrophic organisms (1) such as green plants, algae and some species of bacteria (1). It involves a series of complex chemical reactions (1). Photosynthesis is composed of light stage and the dark stage (1). **Any 4×1 = 4 marks**
20. C **2 marks**
21. C **2 marks**

22. A **2 marks**

23. B **2 marks**

24. D **2 marks**

25. A **2 marks**

26. D **2 marks**

27. D **2 marks**

28. Why leaves of a seedling may appear yellowish

Yellowing of leaves, scientifically known as chlorosis, in plants indicates the deficiency of a particular nutrients or group of nutrients in the soil (1). Examples of such nutrients include nitrogen, Sulphur, potassium and iron (1). Therefore, the leaves of a seedling may appear yellowish when the seedling lacks any or a combination of these nutrients (1). **3×1 = 3 marks**

29. Nitrate and ammonium ions **2×1 = 2 marks**

30. True **2 marks**

31. Experiment to investigate the need for chlorophyll for photosynthesis

a. **Apparatus:** variegated leaf, iodine solution, water, ethanol, beaker, test tube, water trough, white tile, Bunsen burner

Any 4 × ½ = 2 marks

b. Method

- Take a variegated leaf, which has been exposed to sunlight
- Make a sketch of the pattern of green and white patches of the leaf in a note book
- Carry out a starch test on the whole leaf
- Compare the pattern of green patches for starch in the leaf with your original sketch **4 × ½ = 2 marks**

c. **Observation**

The blue-black areas of the leaf correspond to the original green patches (1). The white areas of the leaf show the colour of the iodine (1). **2×1 = 2 marks**

d. Conclusion

Starch is only produced is the green patches because those areas contain chlorophyll (1). Hence photosynthesis cannot occur with chlorophyll (1). **2×1 = 2 marks**

32. False **2 marks**

33. Advise to a young boy not to destroy tomato leaves

- the leaves are the organs of the plant responsible for photosynthesis
- when the leaves are destroyed the plant cannot manufacture food
- the plant will therefore depend on stored food for sometime
- when the stored food finally gets utilized the plant will die

4×1 = 4 marks

Note: Total mark for the CUT is 80.

Appendix H: Table of Specification for KRT

	Behaviours				
Content Area	Knowledge	Comprehension	Application	Analysis	Total
The process of photosynthesis	2	1	2	1	6
Fate of the products of photosynthesis	1	1		1	3
Factors affecting the rate of photosynthesis		1		1	2
The effects of macronutrients and micronutrients	1	1	1	1	4
Biochemical nature of photosynthesis	2	2	1		5
Total	6	6	4	4	20

Appendix I: Sample of KRT items

Instruction: Answer all questions on the question paper

Time allowed: 1 HR

Respondent's Identification No: ……………………………………………….

1. Name the organic product of photosynthesis

   ………………………………………………………………………………..

2. Write the first equation for photosynthesis

   ……………………………………………………………………………….

3. Explain why farmers apply N.P.K. fertilizer to their crops

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4. The light stage of photosynthesis involves

   a. Fixation of carbon dioxide b. the reduction of ribulose bisphosphate

   c. photolysis of water d. oxidation of NADPH to NADP

5. The rate of photosynthesis in plant is high when

   b. Temperature is low b. carbon dioxide concentration is low

   c. Temperature is high d. water content of soil is low

6. Discuss the fate of glucose produced from photosynthesis

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7. Which of the following essential elements plays a role in the synthesis of chlorophyll molecule?

   a. Phosphorus b. magnesium c. calcium d. sulphur

8. Explain briefly why alga are considered autotrophs

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9. Define photolysis

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10. By which one of the following processes does carbon (IV) oxide pass through leaf stomata?

    a. Osmosis b. diffusion c. absorption d. transpiration

11. Which one of the following most appropriately completes the equation written below?

    Carbon (IV) oxide + water → glucose + …….

    a. Starch b. energy c. sucrose d. oxygen

12. Discuss how temperature influences the rate of photosynthesis in autotrophs

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13. The part of a leaf which is most photosynthetic is

    a. Palisade mesophyll b. pericycle tissue c. epidermal tissue

    d. vascular tissue

14. Analyse the importance of NO_3^- in maize nutrition and production

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15. What happens during the light-dependent stage of photosynthesis?

    a. NADP is reduced b. ADP is reduced c. FAD is reduced d. NAD is reduced

16. State one benefit of photosynthesis

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    ……………………………………………………………………………

17. Which cells of a plant are specialised for photosynthesis?

    ………………………………………………………………………….

18. Analyse any three structural adaptations of the leaves of a pawpaw plant to carry out photosynthesis

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19. Analyse how chlorophyll concentration is likely to affect the rate of photosynthesis

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20. State two uses of oxygen produced during the process photosynthesis

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Appendix J: Marking Scheme for the KRT Questions

1. Glucose **2 marks**

2. $4H_2O \rightarrow 4H^+ + 4OH^-$ **2 marks**

3. Why farmers apply N.P.K fertilizer to their crops

-crops need nutrients for strong, healthy growth

-fertilizers are food for plants

-they replace the nutrients that crops remove from the soil

-without fertilizer crop yield would significantly reduce

-provide nutrients not available in the soil **Any 3×1 = 3 marks**

4. C **1 mark**

5. C **1 mark**

6. Fate of glucose produced during photosynthesis

-stored in a form of starch in some plant organs

-used up in the process of cellular respiration

-Some is converted to more complex carbohydrate to make cellulose

-to synthesize protein

-to synthesize lipids for the protoplasm **Any 3×2 = 6 marks**

7. B **1 mark**

8. Why alga are considered autotrophs

Alga are considered autotrophs because they can produce their own food using sunlight, water, carbon dioxide or other chemicals. **2 marks**

9. Definition of photolysis

Photolysis is the photochemical splitting of water molecules (1) into hydrogen ions and hydroxyl ions (1) **2 marks**

10. B **1 mark**

11. C **1 mark**

12. How temperature influences the rate of photosynthesis in autotrophs

-Photosynthesis during the dark stage is controlled by enzymes

-Hence affected by temperature

-An increase of 10ºC effectively doubles the activity of enzymes

-The optimum temperature for photosynthesis in most temperate plants is 30ºC

-Temperature above critical value (40ºC), the enzymes will be denatured

-The rate then decreases rapidly and stops altogether

Any 3×2 = 6 marks

13. A **1 mark**

14. Importance of NO_3^- in maize production

NO_3^- is involved in the synthesis of amino acids, proteins and other complex nitrogen compounds like chlorophyll **2 marks**

15. A **1 mark**

16. One Benefits of photosynthesis

-Provides food for living organisms in the ecosystem

-Provides oxygen for animal respiration

-Purifies the air by removing CO_2 and replaces it with O_2

-Contributes to the reduction in greenhouse effect

-Reduces CO_2 content in the air

-Minimises climate change **Any 1×1 = 1 mark**

17. Palisade mesophyll cells **(correct spelling to score) 1 mark**

18. Three structural adaptations of the leaf for photosynthesis

-Has a broad, flat shape, giving a large surface area to allow maximum absorption of sunlight and CO_2

-Its thin nature allows CO_2 to diffuse easily to mesophyll cells

-Presence of numerous stomata ensure efficient exchange of gases

-Palisade mesophyll cells contain large number of chloroplasts for sunlight absorption

-Large air spaces between the spongy mesophyll cells allow gases to diffuse easily

-Numerous network of veins supplies photosynthetic cells with water and minerals and carries away the products of photosynthesis

-Arrangement of leaves along the stem in a regular pattern minimises overlapping and overshadowing. **Any 3×2 = 6 marks**

19. How chlorophyll concentration affects photosynthesis rate

-Chlorophyll is the site of photosynthesis.

-The amount of chlorophyll in the leaves directly affects the rate of photosynthesis of the plant.

-For example, a variegated will have a lower overall rate of photosynthesis than a green leaf of the same size, because it contains less chlorophyll.

-Some mineral deficiencies also reduce the amount of chlorophyll and therefore the rate of photosynthesis.

-For example, iron deficiency produces chlorosis, seen as yellowing of leaves which results in a corresponding decrease in the rate of photosynthesis

Any 3×2 = 6 marks

20. Two uses of oxygen produced during photosynthesis

-used by plants for cellular respiration

-used by animals to breakdown glucose during cellular respiration

-for oxy-acetylene welding and cutting metals

-to make epoxyethane (ethylene oxide)

-used as antifreeze and to make polyester

-used in burning **Any 2×2 = 4 marks**

Maximum score in the KRT is 50

Appendix K: Sample of students' pre-test work

PRE – TEST ITEMS

Instructions: Answer all the questions on the question paper 19/50

Time Allowed: 1 Hr 10 mins

Student's identification No: ....CF2S1..

1. By which one of the following processes does carbon (IV) oxide pass through leaf stomata?
   a. Osmosis b. diffusion c. absorption d. transpiration (1)
2. Which one of the following most appropriately completes the equation written below?
   Carbon (IV) oxide + water → glucose + ...
   a. Starch b. energy c. oxygen d. sucrose (1)
3. List the importance of each of the following macronutrients in plants
   a. NO_3^- ....
   ....
   b. Ca^{2+} .... (0)
   ....
4. Explain how each of the following factors affects the rate of photosynthesis in plant
   a. Light intensity
   ....
   ....
   ....
   ....
   b. Temperature .... (0)
   ....
   ....
   ....
5. The glucose produced during the process of photosynthesis has the chemical formula of
   a. $C_6H_{10}O_6$ b. $C_6H_{12}O_6$ c. $C_{12}H_6O_{12}$ d. $C_6H_{12}O_8$ (1)

03

6. State any three (3) adaptations of the leaf for photosynthesis
   i. Presence of chlorophyll and stomata
   ii. Photosynthetic cells carrys water
   iii. ....

7. Which of the following foods is produced in the process of photosynthesis?
   a. Sucrose b. cellulose (c) glucose d. fructose

8. The part of a leaf which is most photosynthetic is
   (a) Palisade mesophyll b. pericycle tissue c. epidermal tissue d. vascular tissue

9. Provide the reason(s) for carrying out each of the following activities when testing for starch in a leaf by completing the table below.

Activity	Reason(s)
Leaf is placed in a beaker of boiling water	To kill all active cells in the leaf.
Leaf is placed in a test tube containing alcohol	To decolourise the leaf.
Leaf is washed in a warm water	To kill all the active cells in the leaf.

10. What is the role of water in the process of photosynthesis?
The water combines with carbondioxide to form the glucose.

11. During heavy rains, leaching may lead to
   a. Vigorous plant growth (b) loss of soil nutrients

07

c. Migration of crop pests   d. soil fertility

12. Nitrogen may be lost from the soil through

a. Ammonification   b. nitrification   c. deamination   d. denitrification

13. A farmer intercropped his maize plantation with beans in order to

a. Check soil erosion   b. suppress the growth of weeds

c. Add nitrates to the soil   d. protects crops against grazers

14. The humus content of a soil can be renewed by application of

a. Ammonia fertilizer   b. compost   c. NPK   d. urea

15. What happens during the light-dependent stage of photosynthesis?

a. NADP is reduced   b. ADP is reduced   c. FAD is reduced   d. NAD is reduced

16. The oxygen given off during photosynthesis is obtained

a. By the ionization of water   b. By the combination of carbon dioxide and water

c. By the breakdown of carbon dioxide   d. From excess oxygen taken into the plant

17. Evaluate briefly the importance of the leaf to a plant

The leaf contains chlorophyll which trap sunlight for photosynthesis.

18. Explain briefly how plants contribute to the reduction in climate change?

Plants contribute to the reduction in climate change by making use of carbondioxide which contribute to the reduction of Greenhouse gases in the atmosphere.

19. Discuss the light reaction stage of photosynthesis

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20. State one benefit of photosynthesis

Photosynthesis provides oxygen for animal respiration.

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21. Temperature and oxygen concentration are some of the factors that affect the rate of photosynthesis. **True/False**

22. The average rate of photosynthesis is higher in December than in June. **True/False**

23. Name the products of the light stage of photosynthesis that are useful in the dark stage.

....

24. Which cells of a plant are specialised for photosynthesis?

Palisade mesophyll cells

25. The main product of photosynthesis is an inorganic compound.

True/False

03

Appendix L: Sample of students' post-test work

Conceptual Understand Test (Post-test) Items

Instruction: Answer all questions on the question paper

Time allowed: 1 hr 20 mins.

66/80

Respondent's Identification No: EF2S6

1. Write a balanced chemical equation for photosynthesis
   $6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + 6O_2$
   R=1 P=1 B=1 (2)
2. Name the products of photosynthesis
   Glucose and Oxygen (2)
3. What conditions are necessary for photosynthesis to occur?
   Carbon dioxide and water (2)
4. The light stage of photosynthesis takes place in the thylakoid membrane (2) of the chloroplast
5. Write the first equation for photosynthesis
   $4H_2O \rightarrow 4H^+ + 4OH^-$ R=1, P=1 (2)
6. Which of the following is a factor that affects the rate of photosynthesis? (2)
   a. O_2 concentration (b) CO_2 concentration c. H_2 concentration d. N_2 concentration
7. Write the full name for **RUBP** Ribulose Bisphosphate (2)
8. Name the first product of photosynthesis Glycerate-3-phosphate (2)
9. The dark stage of photosynthesis is controlled by enzyme and therefore not affected by temperature **True/False** (2)
10. Which of the stages of photosynthesis is also called the Calvin Cycle?
    The dark stage (2)
11. Define photolysis Photolysis is the photochemical splitting of water to form hydrogen and hydroxyl ions (2)
12. What observation will you make when testing for starch in a leave?
    A colour is formed which is blue-black (2)

25

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13. The part of a leaf which is most photosynthetic is
a. Palisade mesophyll b. pericycle tissue c. epidermal tissue
d. vascular tissue

14. Analyse the importance of NO_3^- in maize nutrition and production

15. What happens during the light-dependent stage of photosynthesis?
a. NADP is reduced b. ADP is reduced c. FAD is reduced d. NAD is reduced

16. State one benefit of photosynthesis
Photosynthesis provides oxygen for animal respiration.

17. Which cells of a plant are specialised for photosynthesis?
Palisade mesophyll cells

18. Analyse any three structural adaptations of the leaves of a pawpaw plant to carry out photosynthesis
1. Presence of chlorophylly and stomata
2. The leaf has large air spaces between the

Mesophylly cells which allows gases to diffuse more easily (2)

7. The leaf are arranged In a manner to minimise over lapping (2)

19. Analyse how chlorophyll concentration is likely to affect the rate of photosynthesis

Chlorophyll is the site of photosynthesis and its amount in the leafs affects the rate of photosynthesis of the plant. (2) Also certain mineral deficies also reduces the amount of chlorophyll and hence interfer with the rate of photosynthesis. (2)

20. State two uses of glucose produced during the process photosynthesis

1. It is use in ~~durin~~ durning. (0)

2. For Cellular respiration (2)

12

21. An example of a micro-element required by plants is

a. Boron b. calcium c. iron d. nitrogen

22. Which of the following essential elements plays a role in the synthesis of chlorophyll molecule?

a. Phosphorus b. magnesium c. calcium d. sulphur

23. Chlorosis is plants can be reduced by applying

a. Calcium and magnesium b. potassium and phosphorus

c. Sulphur and boron d. nitrogen and iron

24. Micro elements are required in small quantities by plants because they

a. do not actually need them b. can be re-used by plants

c. retard plant growth when in excess d. can be synthesized by plant

25. The mineral salt important for cell wall formation is

a. calcium b. nitrogen c. phosphorus d. carbon

Use the list of essential nutrients below to answer questions 26 and 27

I. Molybdenum II. Carbon III. Nitrogen IV. Copper

26. Which of the nutrients listed above are major nutrients?

a. I and II only b. I, and III only c. II, III and IV only d. II and III only

27. Which of them is/are needed by plants is minute quantities?

a. I only b. I, II and IV only c. II and III only d. I and IV only

28. Explain why the leaves of a seedling may be yellowish in appearance

Yellowing of leaves in plant means that a particular nutrient is not in the soil for the plant to take. For example nitrogen, Sulphur or iron.

29. State the form(s) in which nitrogen is absorbed by plant

Nitrate ion and ammonium ion

12

30. Excessive supply of macro nutrients to plants become toxic and hence may cause plants to die. **True/False**

31. Describe a simple experiment performed by you or your teacher in the laboratory to demonstrate the need for chlorophyll in formation of starch in a plant.

Materials needed are iodine, water, alcohol, beaker, test tube, variegated leaves etc.
The method is that you expose the leaf to the sun. Then you make a drawing of the leaf in a book. After that you do a starch test and compare the leaf with the drawing in the book.
The observation is that a blue-black colour is formed in some places and some place show the colour of the iodine.
The conclusion is that starch is formed in the green areas that contain chlorophyll.

32. RUBP is a 6-carbon compound. **True/False**

33. Explain why you would advise a young boy not to destroy the leaves of a tomato plants in the backyard garden.

The leaves are the site for photosynthesis because they contain chlorophyll. Therefore when the leaves are destroyed the plant cannot prepare food and it will die.

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Appendix M: Sample of students' KRT work

Instruction: Answer all questions on the question paper

Time allowed: 1 HR

Respondent's Identification No: EF2S2

45/50 good

1. Name the organic product of photosynthesis

~~Glucose~~ Glucose (2)

2. Write the first equation for photosynthesis

$4H_2O \rightarrow 4H^+ + 4OH$ (2)

3. Explain why farmers apply N.P.K. fertilizer to their crops

(N.P.K.)
When fertilizer is applied to the crops through the ~~cro~~ soil, the fertilizer contains some essential nutrient lost as a result of depletion of the soil. The lost nutrients are replace by the fertilizer which are absorve by the plant to bust the growth of plant (3)

4. The light stage of photosynthesis involves

a. Fixation of carbon dioxide b. the reduction of ribulose bisphosphate (1)

(c.) photolysis of water d. oxidation of NADPH to NADP

5. The rate of photosynthesis in plant is high when

a. Temperature is low b. carbon dioxide concentration is low (1)

(c.) Temperature is high d. water content of soil is low

6. Discuss how plants make use of glucose produced during the process of photosynthesis

Some is converted to more complex carbohydrate to manufacture cellulose. Also some are synthesis to make protien whiles other are (4)

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also utilised in the process of cellular respiration finally Some of the glucose is stored In the form of starch in Certain plant organs. (2)

7. Which of the following essential elements plays a role in the synthesis of chlorophyll molecule?

a. Phosphorus (b) magnesium c. calcium d. sulphur (1)

8. Explain briefly why alga are considered autotrophs

Algae are Considered as autotrophs because they Can produce their own food making use of Sunlight, Carbondioxide water or other chemicals. (2)

9. Define photolysis

Is the photochemical Spilting of water into hydrogen ions and hydroxyl ions (2)

10. By which one of the following processes does carbon (IV) oxide pass through leaf stomata?

a. Osmosis (b) diffusion c. absorption d. transpiration (1)

11. Which one of the following most appropriately completes the equation written below?
Carbon (IV) oxide + water → glucose + ...

a. Starch b. energy (c) oxygen d. sucrose (1)

12. Discuss how temperature influences the rate of photosynthesis in autotrophs

Photosynthesis during the light independent stage is controlled by enzymes and therefore is affected by temperature when temperature increases the rate of photosynthesis also increase. (6)

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and the vice verser

13. The part of a leaf which is most photosynthetic is

(a.) Palisade mesophyll b. pericycle tissue c. epidermal tissue

d. vascular tissue

1

14. Analyse the importance of NO_3^- in maize nutrition and production

0

15. What happens during the light-dependent stage of photosynthesis?

(a) NADP is reduced b. ADP is reduced c. FAD is reduced d. NAD is reduced

1

16. State one benefit of photosynthesis

Photosynthesis provides oxygen for animal respiration.

1

17. Which cells of a plant are specialised for photosynthesis?

Palisade mesophyll cells. 1

18. Analyse any three structural adaptations of the leaves of a pawpaw plant to carry out photosynthesis

1. Presence of chlorophylly and stomata. 1

2. The leaf has large air spaces between the

05

Mesophilly cells which allow gases to diffuse more easily (2)

3. The leaf are arranged in a manner to minimise over lapping (2)

19. Analyse how chlorophyll concentration is likely to affect the rate of photosynthesis

(2)

Chlorophyll is the site of photosynthesis and its amount in the leafs affects the rate of photosynthesis of the plant. Also certain (2) mineral deficies also reduces the amount of chlorophyll and hence interfear with the rate of photosynthesis. (2)

20. State two uses of glucose produced during the process photosynthesis

1. It is use in ~~durin~~ durning. (0)

2. for Cellular respiration (2)

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Appendix N: Interview Protocol

(Adapted from Gablinske (2014), p.120, A case study of student and teacher relationships and the effect on student learning)

Time of interview: ----------------------- Date: ------------------------

Place: ---

Interviewer: --

Interviewee(s): ---

Interview Questions (few examples for guidance – not detail list)

a. What are some of your perceptions on the use of MIA in teaching and learning photosynthesis and mineral nutrition?

Ans: ---

----

b. On a scale of excellent, very good, good, satisfactory, poor or very poor, how would you rate the views expressed in learning with MIA?

Ans: ---

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c. State some reasons why you will recommend the use of MIA in teaching and learning Biology.

Ans: ---

Appendix O: Observation Protocol

(Adapted from Gablinske (2014), p.121, A case study of student and teacher relationships and the effect on student learning)

Date: --

Time: --

Observation Site: --

Person(s) being observed: ---

Description of observation activity: --

Observation notes (site)	Reflective notes (observer)
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