UNIVERSITY OF EDUCATION, WINNEBA

THE IMPACT OF 5E LEARNING STYLES ON STUDENTS' ACHIEVEMENT IN PHOTOSYNTHESIS IN ADUKROM SENIOR HIGH TECHNICAL SCHOOL

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**A Thesis in the Department of Science Education,
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DECLARATION

Student's Declaration

I, Kumasah, Angella Emefa, 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: Kumasah, Angella Emefa

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: Prof. Yaw Ameyaw

Supervisor's Signature: …………………………………………………..

Date: …………………………………………………..

DEDICATION

I dedicated this research work to my parents – Michael Kumasah and Paulina Kumasah – my husband, Mr. Moses Angmortey Tetteh and daughter, Ropheka Mau-Dzormi Doe Tetteh.

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All glory is to Almighty God for His mercies, constant guidance, sustenance, gift of life and protection. To Him all praises and thanks belong.

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

ABSTRACT

This quasi-experimental research work was conducted primarily to investigate the impact of 5E Learning Cycle Model (LCM) on students' achievement in photosynthesis at Adukrom Senior High Technical School. Also, the study investigated students' misconceptions about photosynthesis and their perceptions of using 5E LCM in teaching and learning the topic under consideration. One hundred third year Biology students of the school were selected as the respondents for the study using purposive sampling technique. This number was made up of 25 male and 75 female students, classified into two groups of control and experimental groups. Academic intervention was meted out separately to the two groups which lasted six weeks. The control group was instructed using the traditional method while the methodology for the experimental group was the used of 5E LCM. Research instruments employed in data collection were tests (pre-test and post-test) and interview. The results showed a significant difference between the post-test and pre-test of groups. The experimental group out-performed the control group. The results therefore proves that the 5E LCM is an effective instructional tool in enhancing students' performance. Regarding the misconceptions of photosynthesis, it was found out that the students perceived the topic to be very complex as it contains a lot of terminologies. The study therefore, recommends the use of 5E LCM as a tool for lesson instruction to be used in the study institution.

CHAPTER ONE

INTRODUCTION

1.0 Overview

The first chapter of this research study outlines the introduction, which covers specific areas such as the background of the study, problem statement and purpose of the study. More specifically, it also indicates the objectives of the study, research questions and the hypothesis to be tested. The chapter concludes with operational definitions of some key terminologies as used in the context of this study, and finally, the organization of the study.

1.1 Background to the Study

Education is a process of active participation of students and teachers to achieve the goal of education by using different forms of work, strategy, teaching aids and media involvement. It enables individuals and society to make all-rounded participation in the development process by acquiring knowledge, ability, skills and attitude (Oskouei & Saemian, 2012). Education is the main tool in the creation of human capital. It is the process of different activities. It involves refining, instruction and exercise. The main aim of education is to evaluate all the teaching and learning process in every field of study (Hannasari & Bangun, 2017).

Learning starts from the birth and occurs in every day of human life. Children learn concepts from many sources; parents, siblings, television, radio, CD, books, computers, museums, zoos etc. Before formal schooling, children construct their own explanations with their everyday experiences. Consequently, children do not enter the classrooms as blank slates, but they enter classrooms with a preexisting knowledge of science concepts (Posner, Strike, Hewson & Gertzag, 1982). "Since 2000, study after study has made it clear that there is an alarming crisis in relation to students' interest in science, either as a possible future career, or as an intrinsic interest that will continue after school" (Fensham, 2008,). The list of countries experiencing declining interest of students in science is on the increase particularly among the developed countries (Fensham, 2008). Most scientists would argue that science is an important tool for understanding the way the world works, for comprehending some of the critical issues of the day, and even for improving citizenship. Also, for many parents, the most compelling rationale might be to develop the skills their children who will need to prosper in a 21st century workforce (BSCS, 2008). However, many students view science as an endless barrage of terms, facts and formulas; all which seem to have little relevance to or connection with their understanding of scientific phenomena and with their world they inhabit (MacGowan, 1997). Further, most research studies have found that science courses have been characterized as boring and irrelevant to the world of the students (Allard and Barman, 1994) and many students have difficulty in learning science (Weiss, 1987; LaPointe, Meade & Philips, 1989; Sheppard, 1997). Students show wide range of difficulties to learn the basic concepts of science. Discovering the reason of it has been target of many studies (Fisher, 1985; Nakhleh, 1992; Chambers & Andre, 1997; Boujaoud, 2004). Several studies revealed that learning science is often difficult for students because their theories about how the world works conflict with scientific understandings they are to learn (Fellows, 1994). Students come into a classroom with their own experiences. One factor which has contributed to low interest in science by students is the method adopted for teaching and learning science. Fensham (2008, p. 20-21) listed four views of students which contribute directly to low interest in science:

i. science teaching is predominantly transmissive.

ii. the content of school science has an abstractness that makes it irrelevant,

iii. learning science is relatively difficult, for both successful and unsuccessful students. Hence, it is not surprising that many students in considering the senior secondary years are saying:

iv. why should I continue studying science subjects when there are more interactive, interesting and less difficult ones to study?

Selection of teaching method is one of the primary principles in education by taking in to account the subject matter, the objective of the lesson and the nature of the learner. Therefore, teaching students how to communicate effectively, cooperate with others and learn independently has become the basics of education (El-sayed, Elmashad, & Ibrahim, 2017).

This unhealthy development in the disposition of students towards science has sparked the search for and development of alternative methods of science teaching and learning which can stimulate students' interest and guarantee an educational system that offers equal opportunities for all. Science education as a field of study is therefore in dire need of methods with qualities such as lesson clarity, promotion of self-activity, promotion of self-development, stimulation of interest and curiosity and relying on the psychological process of teaching and learning to recommend to science teachers. Many students today are learning science in a passive way in classrooms where information is organized and presented to them by their teacher (Moyer, Hackett & Everett, 2007). They noted that "often, the teacher pays little attention to what students already know about science.

Knowledge, which is long lasting and available for use later, is created through the transmission of experience. The expansion of education, creation of new fields of discipline and development of different instructional approaches, calls for detailed assessment of instructional strategies before they are selected to use in science classroom. Also, with the increasing emphasis on lesson clarity, promotion of self-activity, stimulation of interest and curiosity, teaching methods associated with subject matter disciplines, instructional variety, retention rates and life-long learning, there is good reason to explore other instructional approaches for teaching science different from the one predominantly used (lecture) for very long time. This exploration is to determine if the methods have varying effects on students' achievement when compared with the lifelong objectives of teaching science. Students come into a classroom with their own experiences. They construct ideas about the natural world based, in part, on observations of objects, phenomena, and their interactions. With time, these ideas also become linked and tested through their experiences and interactions with the ideas of others (Lunetta, Hofstein & Clough, 2007). If a student uses existing concepts to deal with new phenomena, this is called assimilation. (Posner et al., 1982). However, if there is a discrepancy between the conceptual framework and the new information, student must actively reconstruct the conceptual framework through accommodation (Bodner, 1986). From this point of view, learning in science entails more than just adding new concepts to knowledge. Students' preexisting knowledge may be incorrect, incomplete or ineffective to explain the scientific phenomena. It is obvious that instructors should consider supplementing the lecture format with a variety of active learning teaching strategies that would encourage the students to become aware of their prior knowledge and misconceptions. Ausubel (1968) also stated the most important single factor influencing learning is what the learner already knows. However, research studies, which examine the teaching procedure used in teaching science, revealed that most science courses are taught with the belief that students are empty vessels that need to be filled with large amounts of information (Billings, 2001) and teaching science in most schools is done with the inform-verify-practice procedure (Marek, & Cavallo, 1997). In inform verify-practice procedure, students are informed about what they are to know so they have no experiences to coordinate. That is, the experiences someone else has had are coordinated into a logical system and presented to them. However, Albert Einstein stated that "the object of all science is to coordinate our experiences and bring them into a logical system''(Einstein, 1962).

Therefore, if Einstein is correct, it is obvious that science cannot be taught with the inform-verify-practice teaching procedure (Marek, & Cavallo, 1997).

Students' conceptions which are inconsistent with the ideas of scientists have been called "misconceptions" (Fisher, 1985), alternative conceptions" (Arnaudin & Mintzes, 1985), "naive theories", or "children science" (Gilbert, Osborne & Fensham, 1982). The term "misconception" was used throughout this study to define students' ideas that are in conflict with those generally accepted by scientists. As the literature indicates, misconceptions are pervasive, stable, resistant, and affect the further learning negatively (Anderson, 1986; Griffiths & Preston, 1992). In other words, misconceptions are really big obstacles to promote science learning. Therefore, it becomes very important to find out students' preconceptions and misconceptions before instruction and take them into consideration during the instruction. Today, research studies have indicated that inform-verify-practice procedure do not allow higher level thinking to occur in classrooms but rather relegate science to the memorization of facts. In rote learning, students do not develop hierarchical framework of successively more inclusive concepts, instead they accumulate isolated propositions in their cognitive structure. This causes poor retention and retrieval of new knowledge to solve problems (Uzuntiryaki, 2003). In other worlds, many students taught with traditional learning tend not to learn meaningfully and thus may have difficulty relating what is taught to them in science with other science ideas, and with real world experiences (Novak, 1988). Instead, for meaningful learning to occur, new knowledge must be related by the student to relevant existing concepts in that student's cognitive structure. These observations lead to a new approach to education called constructivist approach. A constructivist approach sees learners as mentally active agents struggling to make sense of their world (Pines & West, 1986). Also, it allows students to construct knowledge, to think and to learn. Constructivist ideas have had a major influence on science educators over the last decade (Appleton, 1997). The learning cycle approach also promotes the constructivist philosophy whereby students construct knowledge by identifying and testing their existing understandings, by interpreting the meaning of their ongoing experiences, and by adjusting their knowledge frameworks accordingly (Ewers, 2001). Karplus (1960) also argued that the teaching of science requires more than content. Teaching requires a plan derived from both the discipline of science and the manner in which students learn. He called the teaching procedure that was invented to satisfy those requirements the learning cycle. The learning cycle moves children through a scientific investigation by allowing them first to explore materials, then to construct a concept, and finally to apply this concept to new ideas (Marek & Cavallo, 1997). Further, all phases of the learning cycle incorporate the Piagetian approach into a succinct methodology of learning: experiencing the phenomena or concept

(Exploration Phase), applying terminology to the concept (Concept/Introduction), and application of the concepts into additional conceptual frameworks (Concept Application) (Odom & Kelly, 2001).

The learning cycle, the antithesis of inform-verify-practice approach in science, promotes meaningful learning because students must construct, formulate, and explain their ideas from their own experiences. The students are not given answers, which tend to close their minds and stop their process of making links and meaning of their experiences. Textbook definitions and readings are used by students only after having direct experience with the phenomena. Thus, students first form a knowledge base of understanding of the concept that was central to their concrete experiences in the exploration. This knowledge base is the relevant prior knowledge upon which to link new ideas they learn in the concept application phase of the learning cycle. Furthermore, the concept application phase typically includes many activities that help students to link ideas and relate them to their everyday lives. Also,

Piaget labeled this process of linking ideas within the mental structure as “organization” (Marek & Cavallo, 1997). In addition, the learning cycle was intended to attain many national goals and standards of science education for the twenty-first century (National Research Council, 1996). The learning cycle was designed to be consistent with the nature of science and to promote critical thinking through inquiry, collaborative grouping, and the construction of new ideas. The development of the ability to think has long been accepted as a central purpose of education (Educational Policies Commission 1961; American Association for the Advancement of Science, 1990) because the ability to think independently allows individuals in our society to make choices and enjoy true freedom. Thus, educators need to help children- who represent the future leaders and decision makers of our society- develop the ability to think logically (Marek & Cavallo, 1997). The ability to think is based on the use of the rational powers of the mind (Educational Policies Commission, 1961). Also, Marek and Cavallo (1997) equate ability to think with students' development and use of the rational powers: classifying, comparing, evaluating, analyzing, synthesizing, imagining, inferring, deducing, recalling, and generalizing. All phases of the learning cycle lead students to develop their rational powers. The exploration phase of the learning cycle is the time during which the major assimilation that leads to conceptual understanding takes place. In making this assimilation students classify the results they receive, which means that they compare them and comparing results requires at least a minor evaluation. Students use several of the rational powers, therefore, in just the act of exploring. Before, term introduction, students must make a thorough analysis of the data resulting from their exploration. Term introduction is obviously a synthesis incorporating the use of imagination. Classifying, comparing, evaluating, and inferring are necessary in formulating the concept. All these activities lead to transference of the data received through the context of exploration to the context of knowledge construction. Such activities also make evident why accommodation takes place during the term introduction phase. In the concept-application phase, the newly acquired knowledge is immediately put to use in a new context and with new materials. This causes students to recognize their fresh understanding of the concept and generalize about it. Most certainly, students are using deduction throughout this entire learning cycle phase. In light of the foregoing, it can be concluded that the combination of curriculum organization and classroom teaching procedures using the learning cycle leads students to achieve the central purpose of education, that is, they are developing the ability to think (Marek & Cavallo, 1997). In addition to help students acquire scientific knowledge; another goal of science education is to understand its development. In other words, science education should not only teach what science is, but also how scientific knowledge is constructed through a series of complex interactions among different views, such as cultural and social (Huang, Tsai, & Chang, 2005). Traditional science education focuses mainly on the acquisition of scientific facts, but very little on the process as well as the nature of developing scientific knowledge (Duschl, 1990). That is science curricula, teachers, and students may not have appropriate understandings of the nature of science, and most of them express empiricist-aligned (in contrast to constructivist) views about the nature of science (Lederman, 1992). However, understanding the nature of science is important because it not only should help students function in our society, but also should enrich their lives by making them insiders who can share in the science adventure story as it unfolds (American Association for the Advancement of Science, 1993). Findings indicate that the learning cycle influenced learner's conceptions of the nature of science and science instruction (i.e., Senneca, 1997). In this study, we used another version of learning cycle, which is called 5E Learning Cycle Model (Engage, Explore, Explain, Elaborate and Evaluate), because 5E sequence automatically structures constructivist, inquiry–based learning while addressing content required by high school students (Wilder & Shuttleworth, 2005). This model is designed to incorporate all aspects of constructivist learning environments by engaging students and allowing students to explore the concepts being introduced, discover explanations for the concepts they are learning, and elaborate on what they have learned by applying their knowledge to new situations. Throughout the process the model offers multiple opportunities for evaluation of students' understanding. (Bybee, 1993; MaryKay & Megan, 2007). For this reason, in the present study, we concerned with students' misconceptions about photosynthesis in plants and instructional methods to improve students' understanding of photosynthesis in plants. This study investigates the effects of three instructions; 5E learning cycle-based instruction (5E-LCBI), and traditional instruction (TI) on Senior High School understanding of photosynthesis in plants at Adukrom Senior High Technical School.

1.2 Statement of the Problem

The indispensability of science in the development of our society has been universally acknowledged, although the output of its teaching and learning is still not encouraging. Many reasons could be cited for this poor performance among which were the prevailing instructional practices that did not actively involve students in the learning process and seemed to prevent them from taking charge of their learning (Francisco, Nicoll & Trautmann, 1998). Other students also perceived biology to involve a lot of reading, making it difficult for them to learn (Mucherah, 2008). Additionally, according to Anthony-Krueger (2007) inadequate and poor practical sessions in the laboratory may be contributing factors to students' poor performance in biology. Some students see the subject to be difficult which, according to Abdul-Mumuni (1995), is influenced by their religious and cultural backgrounds. Also, Soyinbo, Eke, and Ato (as cited in Shaibu and Olarewaju (2007) attributed students' underachievement in Biology to factors such as teachers' qualification, experience, interest and resourcefulness. Fisher and Fraser (1981), Mynt and Goh (2001) noticed that class size in the Biology classroom environment has influence on the achievement of students in Biology. Aside the above reasons for students' underachievement, the approach to teaching and learning of Biology may also be a contributing factor. Also, some of the methods of teaching do not align themselves to the teaching of some topics hence are seldom used by teachers (Tamakloe, Amedahe & Atta, 2005). This seems to cause students to inadequately understand the lessons they are taught hence, might cause them to memorize facts only for examinations and thereafter promptly forgetting what they have learnt. This may be due to the fact that, knowledge does not become internalized and is not transferred between topics and across subjects. Meaningful learning may not be taking place as expected. Anamuah–Mensah, Otuka & Ngma-Wara (1995) emphasised that, “the present state of science instruction in Ghanaian schools...calls for an introduction of more innovative and effective teaching and learning techniques” (p. 67). The traditional method, which was revealed to militate against students’ participation and engagement in the learning process, and also results in their poor achievement is still commonly used by teachers in Ghana.

Literatures revealed that in biology, photosynthesis is a very challenging concept, and it is difficult to understand simply by learners. Eke (2016), noted that the concept of photosynthesis a very abstract concept for students because of its biophysical and biochemical nature. Therefore, it requires the implementation of innovative teaching and learning methods. The study by Dimec and Stragar (2017), revealed that in any school level all students learn about photosynthesis by lecture learning method. Consequently, students face many difficulties to understand the concept of this fundamental process. Researches also showed that students have many misconceptions in relation to photosynthesis. For example, as stated by Kele and Kefeli (2010), students cannot understand the concept of photosynthesis because they have some misconceptions like plants do not undergo respiration (when, in, fact plants can do respire), carbon dioxide is harmful to plant (but, in fact, carbon dioxide is important to plant as raw material for making glucose) and the main role of sunlight for the plant is to make plants more attractive in color. In the other study, many students have common misconceptions and they believe that plants get their food from the soil (Näs, 2010). In addition to this, students also have other misconceptions like plants get their mass from the soil (Connell, 2008). Therefore, to overcome these problems, mentioned above from researchers' finding and experience, there is a need to strike a balance of effective teaching method for biology subjects especially for photosynthesis. This is to ensure that students achieve and retain what they are expected to learn in a given lesson for resultant achievement in SHS. This prompted the quest for an innovative method like the 5E learning model. The 5E LCM has evolved and been embraced widely in Turkey, United States and Internationally. Educators in those countries believe it works so well in improving achievement of all categories of student in science subjects.

It appears however, that 5E LCM of instruction is not widely used in senior high schools in Ghana. Hence our senior high school students may not be benefiting from the advantages of 5E LCM.

1.3 Purpose of the Study

The purpose of the study was to find out the impact of 5E learning styles on students' achievement in photosynthesis in Adukrom Senior High Technical School

1.4 Objectives of the Study

The objectives of the study were to:

1. examine any significant difference between the pre-tests performance of the control and experimental groups before the intervention.
2. examine any significant difference between the post-tests scores of the experimental and control groups after introducing the experimental group to 5E learning approach.

3. investigate the perceptions of students about the use of 5E Learning Cycle Model approach in teaching and learning photosynthesis in ASHTS
4. diagnose the factors that impede students achievement in photosynthesis as a concept.

1.5 Research Questions

1. To what extent is the control group's pre-test score significantly different from that of the experimental group before the intervention?
2. To what extent is the experimental group's post-test score significantly different from that of the control group after introducing the experimental group to 5E learning models?
3. What are the perceptions of students about the use of 5E LCM approach in teaching and learning photosynthesis in plants in ASHTS?
4. What factors impede students achievement in photosynthesis as a concept?

1.6 Null Hypothesis

1. HO_1: There is no significant difference in the performance of the pre-test scores of the control group and the experimental group.
2. HO_2: There is no significant difference in achievement in the cognitive levels between students taught with the 5E learning cycle approach and those taught with the traditional method.

1.7 Significance of the Study

It is envisaged that when the findings are made accessible, students, teachers and researchers of ASHTS would be the beneficiaries in that: The study would help students on the right way of learning the concept of photosynthesis as well as its importance in life process. In addition to that, it would develop students' ability to understand concepts through the use of the 5E learning cycle approach, and again help them to perform better on the topic of photosynthesis. It would help teachers of ASHTS to learn how to use the 5E learning cycle approach in the teaching of the process of photosynthesis. The finding of the study may boost teacher-student interaction in biology class because it is an activity-based learning method that may lead to positive and meaningful learning of the subject. The outcome of the study would help Biology teachers in ensuring the proper implementation of 5E LCM during Biology lesson and in organising their instructional activities in order to ensure a stable retention of the concepts. The finding of the study would also be of importance to any teacher of the school who is interested in developing a curriculum, particularly biology textbook.

In addition, it would also be of significance to other researchers who are interested in using the 5E learning cycle approach and conducting similar studies with different participants.

1.8 Delimitation of the Study

This study was delimited both conceptually and geographically. Conceptually the study was delimited to the effectiveness of 5E learning cycle approach on SHS students Achievement in photosynthesis in plants in Adukrom Senior High Technical School. The topic photosynthesis was chosen by the researcher because this topic is a very abstract and challenging concept as the topic is associated with a lot of terminologies and chemical reactions and students face many difficulties to understand this concept. In addition to this, the knowledge and information about photosynthesis is essential because this process affects living thing either directly or indirectly. Geographically the scope of the study was delimited to Adukrom Senior

High Senior High Technical School. The researcher selected this school so as to make the study manageable in terms of time, resources and distance. The study was additionally delimited to an aspect of biology focusing on photosynthesis in the SHS elective biology syllabus.

1.9 Limitation of the Study

This study was also constrained by instructional materials like laboratory equipment, chemicals, and water in the laboratory because the method was activity oriented and it required different instructional materials.

Also, the researcher being the teacher could not get enough opportunity to collaborate in an intensive way with the other colleague Biology teachers as regards the teaching of the concepts of the process of photosynthesis, hence might not have been able to factor their challenges and problems into the intervention. This might also influence the results obtained.

1.10 Operational Definition of Key Terminologies

1. **Photosynthesis:** Photosynthesis is the chemical process by which water and carbon (IV) oxide are combined in the presence of sunlight and chlorophyll to form glucose as the main product and oxygen is a by-product.
2. **Assimilation:** It is the act of using an existing concepts to deal with a new phenomena.
3. **Conception:** A basic understanding of a situation or a principle.
4. **Misconception:** An idea which is wrong that has been based on a failure to understand a situation**.**
5. **Preconception:** An idea or opinion formed before enough information is available to form it correctly.

6. **5E Learning Cycle Model:** It is a method of teaching in science education which is grounded upon cognitive psychology, constructivist theory of learning and best approaches in science instruction. The term was used interchangeably with Learning Cycle Based Instruction and Learning Cycle Instructional Model.
7. **Engagement:** It is a learner-centered phase of instruction in which the science facilitator assesses the student's prior knowledge about the topic in order to identify possible misconceptions.
8. **Exploration:** It is also a learner-centered phase of instruction which assists the learner with a common, tangible learning experiences. It encourages the application of process skills in the students.
9. **Explanation:** It is a "minds-on" stage of instruction which is more of teacher-directed to enable learners use their prior knowledge to explain their comprehension and to ask questions concerning the concepts under exploration.
10. **Elaboration:** It is an activity-oriented phase of instruction which encourages learners to put into action their comprehension of new concepts, while reinforcing new techniques for in-depth and broader comprehension of the concepts.
11. **Evaluation:** It is a form of assessment that takes place in inquiry-based setting and embraces both formal and informal assessment techniques such as portfolios assessment, performance-based assessment, concept maps, physical models etc.

12. **Cooperative Learning:** It is a method of instruction which deals with the organization of learners into smaller groups or cohorts so that they can perform tasks together in order to maximize one other's learning experiences.

1.11 Organisation of the Study

Chapter one commences with the introduction section and provides a general overview of this research study. Problem statement as curtailed in this work was also introduced. Besides, the chapter also discusses the main purpose of the study, limitations, delimitations as well as the significance in relation to past researches. The chapter also provides the specific objectives, research questions and hypotheses. It then concludes with operational definitions of technical terms as used in the chapters that followed.

The second chapter of this thesis was concentrated on review of related literature. The review provides an insight into the theoretical framework of the study and science education in Ghana. It was focusses attention on the learning of biology, traditional method of teaching, historical background of photosynthesis, the 5E learning cycle model and implications for the science teacher.

The third chapter outlines the methodology employed in the research study. The chapter discusses the research design, the study area and the population of the study. It also focusses on the instrumentation and data analysis procedure.

Chapter four outlines the research findings and its discussions while chapter five provides the summary, conclusions, recommendations and suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter presents the reviews of related literature to the topic under study. The reviews were organized under the following sub-headings: Theoretical Framework, Science Education in Ghana, The Study and Learning of Biology, Cooperative Learning and Alternate Traditional Method. Other areas discussed include historical background of photosynthesis, Importance of Cooperative Instructional Method, Models of Cooperative Teaching Methods as well as the 5E Learning Styles.

2.1 Theoretical Framework

The research was conducted based on the constructivism theory of learning science. Constructivism is one of the most influential theories in contemporary learning theories. Although it has become popular only recently, the origins of constructivism are believed to date back to the time of Socrates, who claimed that teachers and learners should talk with each other and interpret and construct the hidden knowledge by asking questions (Erdem, 2001). Gruber and Voneche (1977) also state that the term constructivism most probably is derived from Piaget's "constructivist" views (1977), as well as from Bruner's (1996) "constructivist" description of discovery learning. Furthermore, Perkins (1992) points out that constructivism has multiple roots in psychology and philosophy of this century: the developmental perspective of Jean Piaget (1970) and the emergence of cognitive psychology under the guidance of figures like Bruner (1966b). The constructivist stance maintains that learning is a process of constructing meaning; it is how people make sense of their experience.

Mvududu and Thiel-Burgess (2012), state that constructivism is widely touted as an approach to probe for children's level of understanding and to show that that understanding can increase and change to higher level thinking. Constructivism describes the way that the students can make sense of the material and also how the materials can be taught effectively. With Constructivism as an educational theory in mind, the teachers should consider what students know and allow their students to put their knowledge in to practice. Constructivism as an educational theory holds that teachers should first consider their students' knowledge and allow them to put that knowledge in to practice (Mvududu & Thiel-Burgess, 2012). Phillips (2000), writes about a number of constructivist traditions. He proposes that educational constructivism itself includes a number of variations and the two most popular types of these variations are:

1) Jean Piaget's personal constructivism.

2) Lev Vygotsky's social constructivism

Piaget and Inhelder (1969), suggest that discovery is the most important and fundamental basis of learning. While Vygotsky (1978) believes that Piaget's emphasis focuses too much on internal processes of individuals. Vygotsky considers cognitive development primarily as a function of external factors such as cultural, historical, and social interaction rather than of individual construction. Vygotsky believes that people master their behavior through psychological tools and he introduces language as the most important psychological tool. Many educators such as Bailey and Pransky (2005) agree with Vygotsky (1978) about the importance of culture in construction of knowledge, yet Bailey and Pransky (2005) emphasize that pedagogical theories such as constructivism don't consider the deep impact of culture on learning and knowledge.

However, the following parts show whether knowledge is viewed as individual construction has implications for the ways in which learning is conceptualized, it has implications for the ways in which learning is conceptualized (Mvududu & Thiel-Burgess, 2012).

Due to complexities and diversity of perspectives on constructivism, Hoover (1996) introduces a common set of principles for these perspectives that can be operationalized. Hoover expressed two important notions which encompass the simple idea of constructed knowledge. The first notion is that learners construct new understandings using their current knowledge. In other words, the learners' prior knowledge influences their new knowledge. The second notion is that learning is not passive. Instead, learning is an active process in which learners negotiate their understanding in the light of what they experience in the new learning situation. If what learners encounter is not consistent with their current understanding, their current knowledge can change in order to accommodate new experience. Thus, learners cannot be passive and they remain active throughout this process. Cook (1992) also advocates the use of negotiation in the curriculum. When learners negotiate, ask questions, and try hard to find the answers themselves, what they learn will be more meaningful to them (Cook, 1992). In constructivism, learning is represented as a constructive process in which the learner is building an internal illustration of knowledge, a personal interpretation of experience. This representation is always open to modification, its structure and linkages forming the ground to which other knowledge structures are attached. Learning is then an active process in which experience has an important role in understanding and grasping the meaning. This view of knowledge does not necessarily reject the existence of the real world, instead it agrees that reality places constrain on the existing concepts, and contends that all individuals' knowledge of the world is the interpretations of their experiences. Furthermore, conceptual growth is the result of various perspectives and the simultaneous changing of individuals' internal representations in response to those perspectives as well as through their experience (Duffy & Jonassen, 1991).

Piaget's constructivism which is based on his view of children's psychological development insists that discovery is the basis of his theory. Piaget (1973) argues that to understand means to discover or reconstruct by means of rediscovery. Piaget discusses that children go through stages in which they accept ideas they may later change or do not accept. Therefore, understanding is built up step by step through active participation and involvement and learners cannot be considered as passive in any of the steps or stages of development.

Contrary to Piaget constructivism, Bruner (1973) states that learning is a social process, whereby students construct new concepts and knowledge based on their current knowledge. In this view of constructivism, the student selects information, constructs hypotheses, and makes decisions, with the aim of integrating new experiences into his existing knowledge and experience. Bruner emphasizes the role of cognitive structures for providing meaning and organization of experiences and suggest learners to transcend the boundaries of the given information. For him, learner independence lies at the heart of effective education and he argues that this independence can be increased when the students try to discover new principles of their own. Moreover, curriculum should be organized in a spiral manner so that students can build upon what they have already learned.

Hoover (1996) argues that constructivism has important implications for teaching. First, teaching cannot be viewed as the transmission of knowledge from enlightened or known to unenlightened or unknown. Constructivist teachers are not monologue teachers who just teach completely new lessons. Rather constructivist teachers have the role of guides for the students and provide their students with opportunities to test the adequacy of their current understandings.

Second, constructivist teachers consider the prior knowledge of their learners and provide learning environments that exploit inconsistencies between learners' current knowledge and their new experiences (Clements, 1997; Hoover, 1996). The difference between learners challenges the teachers and does not allow them to use the same method or the same materials while teaching to these students.

Third, since learners' involvement is emphasized in the constructivism, the teachers must engage students in learning, and bring their students' current understanding to the forefront (Hoover, 1996). Constructivist teachers can ensure that learning experiences include problems that are important to the students, and are not just related to the needs and interests of teachers and the educational system.

Fourth, Hoover (1996) reminds that sufficient time is needed to build the new knowledge actively. During this time, the students reflect on their new experiences and try to consider the relationship between these experiences and the previous ones in order to have an improved (not "correct") view of the world.

Similar to the effect of negotiation as an important aspect of a constructivist classroom on learning, negotiation also unites teachers and students in a common purpose. Smith and Scharmann (1999) confirm that negotiating curriculum means "custom-building classes every day to fit the individuals who attend" (p. 1).

Constructivism believes that learner's conceptions of knowledge are derived from a meaning-making search in which learners construct individual interpretations of their experiences. The learners' constructions during the examination, questioning and analyzing of tasks and experiences yield knowledge whose correspondence to external reality may have little verisimilitude. However, most of the learners' constructions is filtered through a process of social negotiation or distributed cognition (Brown, Ash, Rutherfored, Nakagawa, Gordon, & Campione, 1995).

In constructivism, teachers and peers support and contribute to learning through the concepts of scaffolding, cognitive apprenticeship, tutoring, and cooperative learning and learning communities (Brown, 1994; Rogoff, 1998).

In a constructivist classroom, teachers create situations in which the students will question their own and each other's assumptions. So, a constructivist teacher needs to create situations that challenge the assumptions of traditional teaching and learning. Tarule (1986) cited in Gray (1997) report that at the constructivist level of knowing and thinking, we always reevaluate our assumptions about knowledge; our attitude towards "the expert" is transformed; we do not have any problem by ambiguity but are enticed by complexity; and we take on a never-ending quest for truth and learning where truth is seen as a process of construction in which the knower participates. A constructivist teacher's perception of expertise in the classroom is based on the experience of his or her students in interaction with each other and with their teacher, and his or her tolerance of ambiguity is high as evidenced in the tendency to create complexity

Lester and Onore (1990) indicate that teachers' personal beliefs about teaching (their construct systems) are important and determine the kinds and extents of changes they are able to make. Also, Lester and Onore state that teachers view teaching and the situation through the lens of their personal construct system. Thus, the main construct affecting a teacher's ability to teach in a transactional, constructivist way is the belief that knowledge is constructed by human beings. Further, teachers would need to make a shift in thinking and change what they believe about knowledge in order to really change their teaching.

2.2 Science Education in Ghana

The general goal of the science education in Ghana, according to the Ministry of Education Youth and Sports MEYS (2004), in the report of educational reforms review committee, is to provide relevant and quality education for all Ghanaians, especially the disadvantaged to enable them to acquire skills which will make all functionally literate and to facilitate poverty alleviation and promote the rapid socio-economic growth of the country. The vision of the educational ministry to achieve the above goal is through the following action plans; making science education more relevant to national goals and aspiration, by focusing on science, vocational and technical education; Expanding access to science and technology education at all levels of education; Raising the quality of teaching and learning of science and technology for effective outcomes. This means that the basic school curriculum must be designed to build on integrated science programme with the aim of providing fundamental knowledge and understanding of basic science concepts. Fensham (2000) was quick to add that, for children to understand science concepts, requires that they wrestle with how those concepts are more satisfactory than their own current beliefs. This implies therefore that learning science effectively requires the direct involvement of students with many teaching learning materials and much discussion on how to interpret their observations. Also, science has to be experimental in order to stimulate and sustain student interest and to provide holistic learning experience and develop skills across interconnected disciplines. Barton and Tobin (2001) added that the rural schools have more severe problems than their counterparts in the urban areas as wells as students with handicapped and learning disabilities. He further pointed out that part of the curriculum for these students contain many overloaded major topics, many subtopics with excessive details that make teaching and learning difficult. Many high school teachers lack the necessary skills and know-how to develop, design and undertake age-appropriate inquiry-based practical science lessons for their students. This compels teachers to focus entirely on the theoretical aspect of science, sometimes leaving students confused and creating an erroneous impression that science is difficult and abstract. Nevertheless, the purpose of school is to promote learning and the science teacher holds it as a duty to help students to learn.

Ghana has seen various forms of educational reforms since the attainment of independence in 1957. Until mid-1980s, the main focus of the reforms was on development of new curriculum at all levels of education. The range of science content was expected to extend beyond the traditional conceptual content of physics, chemistry and biology to include application of science and technology. Despite this, one of the most significant aspects of the new science curriculum in Ghana was only a pragmatic reduction in range of content in the 1980s and 1990s. This has resulted in the retention of much of the traditional content with little new materials on technology and development at the basic level of education. Hence, students find the science they are learning at school isolated from their everyday experiences. It is therefore not surprising that more recently, there has been general agreement from the public that the general educational reform in 1987 has failed to meet expectations in terms of coverage, quality, equitableness and economic utility (MEYS, 2004). Science can no longer be detached from the values and priorities of the societies in which it is embedded. For this reason, the evaluation of science education curriculum should be an ongoing process that provides input and feedback to guide change and offer directions for the programme and its modification.

Biology is a natural science discipline that involves the study of life and living organisms, including their physical and chemical structure, function, development and evolution. Despite the broad scope and complexity of science, there are certain unifying concepts that consolidate it into simple, coherent field. Modern biology is a vast field composed of many branches. In general biology recognizes the cell as the basic unit of life, genes as the basic unit of heredity and evolution as the engine that propels the creation of new species. It is also understood that all organisms survive by consuming and transforming energy and by regulating their internal environment. Sub-disciplines of biology are defined by the scale with which life is studied, and the methods used to study them. Biochemistry examines the rudimentary chemistry of life; molecular biology studies the complex interactions among biological molecules. Cellular biology examines the basic building blocks of life. Ecology examines how organisms interact in their environment. Biologists study all the above disciplines to make life comfortable on this earth. For example, Biologists study the intimate details of the human brain, the composition of our genes and even the functioning of our reproductive system.

The study of Deoxyribonucleic Acid (DNA) has enable us determine much of our innate capabilities and predispositions to certain forms of behaviors and illnesses. DNA sequencing has played major roles in criminal cases as well as reversal of death penalties for many wrongly convicted individuals. More so, many individuals are now turning to herbal medicine to ease arthritis, pain, improve memory, as well as our moods. Biology helps he scientists to deduce what kind of nutrition and exercise would best work on the human body for health, longevity and prolonged physical performance. Treatment vaccines and cures for ailments and diseases are mainly an outcome of biology researchers.

2.3 The Learning of Biology

Osborne and Collins (2000) proposed that the learning cycle in children consists of exploration which is the manipulation of materials, investigating, testing of hypotheses, reflection that is more important on the activity. Young (1990) also says that if you are to teach science (biology) well, you need to use a well-organized classroom with the right kind of specimen and also one need to prepare carefully. He continued that teachers often think that they cannot teach science without experience and complicated apparatus. It is certainly true that some apparatus are necessary but most of the things needed can be collected or made with the help of students. Biology is the study of life and teaches us about ourselves and the natural world around us. A good starting point when studying biology is to admire the perfection of nature and the principles of life.

According to Tekkaya, Özkan and Sungur (2001), Student's difficulties in learning biology have been studied by various researchers across the world. Many concepts and topics in biology include protein synthesis, respiration and photosynthesis can be perceived as difficult to learn by secondary school students. Tekkaya, Özkan and Sungur (2001) also found that hormones, genes and chromosomes, mitosis and meiosis, the nervous system were also considered difficult concepts by secondary school students. Experiencing difficulties in so many topics in biology negatively affect students' motivation and achievement (Ozcan, 2003). Students' difficulties in many topics in biology have stimulated researchers to investigate why students experience such difficulties and how to overcome these difficulties. There are many reasons why students have difficulties in learning biological concepts (Lazarowitz & Penso, 1992; Cimer, 2004; Zeidan, 2010). The nature of science itself and its teaching methods are among other factors, the reasons for the difficulties in learning, while according to Lazarowitz and Penso (1992), the biological level of organization and abstract nature of concepts make biology learning difficult. Overloaded biology curricula, the abstract and interdisciplinary nature of biological concepts and difficulties with the textbooks are the factors preventing students from learning. This overloaded curricular may lead the students to memorize. This of course prevents meaningful learning. Fraser (1998) indicates that there is a close relationship between students' perception of their classroom learning environment and their success. Osborne and Collins (2001) reported that students diminishing interest in learning science (biology) was due to the curriculum content being overloaded and not generally related to working life. The lack of discussion of topics of interest, the absence of creative expression opportunities, alienation of science from society and the prevalence of isolated science subject. Teacher's style of biology teaching and teaching methods and techniques may also affect students learning in biology (Cimer, 2004). If students are not happy about the way biology is taught, they may show disinterest in the negative attitude towards biology and its teaching. In addition to determining the factors that negatively affects the students learning in biology, understanding students view on what makes their biology learning effective is crucial as many researchers suggest that in order to improve the quality of biology and learning in school, student views must be taken into consideration by researchers, teacher educators, schools and teachers (Fullan, 1991; Macbeath & Mortimore, 2001; Cimer, 2004; Ekici, 2010). The authors argued that what students say about teaching and learning and schooling is not only worth listening to but provides an important foundation for thinking about ways of improving teaching and learning. More so, it is thought that how students perceive the learning environment affects their attitudes toward biology and its learning (Atilla, 2011). Therefore, understanding secondary school students' perception of biology will help policy makers, teachers and teacher educators to plan more effective teaching activities that can help students learn biology better and have more positive attitudes towards it. Reasons for why the students have difficulties to learn these topics in biology are:

1. The concepts topics are overloaded giving them the opportunity to memorize.

   When text and classroom activities do not appear to be relevant to student's daily lives and do not include practical work or experiment, students may consider biology a science that requires the memorization of factual knowledge. When they think this way, perhaps, students may not connect biology with their daily lives. (Roth, Druker, Garnier, Lemmens, Chen, Kawanaka, Rasmussen, Trubacova, Warvi, Okamoto, Gonzales, Stigler & Gallimore, 2006).

2. The next factor affecting the students learning in biology was the way in which it was taught. According to research, biology topics are taught by

lecture method of teaching, which are teacher - centered lessons. Practical work and student-centered activities in biology classes were merely used. Another related way biology is taught was the lack of relationship between what was taught in the biology classroom and students' daily lives.

3. More so some of the teachers lack mastery in biology and teaching negatively affected their learning. Biology teachers usually prefer to employ mainly the traditional teaching approaches and techniques (Cimer, 2004). Biology lessons are mainly run in a teacher-centered manner; teachers transfer the knowledge that they have and that is written in the textbooks without conducting student-centered activities. This of course has negative effects on students' attitudes towards biology and their motivation to learn. Indeed, Zoller (2000) asserts that teacher centered or traditional lessons can be non-productive and, in some cases, detrimental to student learning. Therefore, teachers' competence and knowledge in both biology as a discipline and its teaching are crucial for enhancing students learning.
4. Furthermore, students learning and study habits were one of the reasons they had difficulties in learning biology.

2.4 Traditional Method of Teaching

This is also referred to as conventional method or expository method of teaching. It is also referred to as the lecture method of teaching, and is the oldest method of teaching. It is mostly described as teacher-centered, teacher dominated, teacher activity method, or top-down transmission teaching. The role of the student is less active and more passive in the teaching and learning interaction.

In Ghanaian secondary schools, traditional method is most often used by Biology teachers for instruction. Teachers occasionally may demonstrate a process for students to observe, engage students in brief discussion and questioning, and often use illustration from diagrams, charts and realia. Discourse between teacher and student is minimal, teacher mostly does the talking. Wood (2007) observed that Biology teachers in the secondary schools introduce lesson followed by explanation and demonstration. Wood noticed that most schools had inadequate realia, charts and diagrams hence sometimes illustrations are missing from teaching. He observed that few questions are allowed from students of which teachers answer. After each explanation, teacher dictates copious notes for students to write. Wood reported that during his research, he inspected the notebooks of the students and found out that all of them had the same notes, indicating that they had their notes solely from their Biology teachers. He reported that teaching was direct from teacher to learner.

According to Tamakloe *et. al.* (2005), for students to benefit fully from such a method which is teacher centered, teacher must prepare adequately, reading from many sources to get quality information. This will help him get mastery over the subject matter leading to good delivery. The teacher should be able to get the attention of the students from the beginning of the lesson and sustain it to the end. Teacher stimulates and excites students to arouse their curiosity. This will make them pay rapt attention to the teacher. The teacher should also be audible enough and make frugal use of illustrations, right gestures and deliver coherently and sequentially. They agreed that the variation of the voice of the teacher prevents monotone and this may give clues to students on important.

The teacher should get a reasonable speed by which all students can cope with. He should not be too slow or too fast. If he is too slow, students may feel lazy or even sleep; and if he is too fast students may not be able to write and comprehend at the same time. This may lead to a lot of 'pot holes' to fill which may frustrate students. The teacher must therefore judge the amount of information which he can effectively deal with within the specified period allotted (Tamakloe *et. al.* 2005). Also, the language used by the teacher should be at the level and comprehension of students. The language or expression should be familiar and simple. The teacher should judiciously plan repetition to iterate major issues raise in the lesson. Dictation of notes is often frowned upon by some educationists since they believe it will make students think what the teacher gives to them in the notes is the ultimate or all there is about the topic. Tamakloe *et. al.* (2005) posited that, in the secondary schools if the teacher resorts to giving students notes he must be convince whatever he decides to dictate to his students are of great importance and they must have it verbatim. Normally, students are expected to make their own notes. To help students get an overview of the lesson, the main points, issues raised in the lesson must be summarized.

2.4.1 Merits of traditional method

Tamakloe *et. al.* (2005) enumerated the merits of traditional method as follows:

i. It provides great opportunity for students to learn to take down notes.
ii. It helps provides information on topics which are not available or easily accessible to students.
iii. The teachers have greater control over what is being taught in class.
iv. Logistically traditional method is often easier to create than other methods of instruction.

v. The traditional method enables a great amount of course content to be covered in the face of a heavy loaded syllabus or programme of instruction.

vi. The traditional method makes for economy since a large number of students can be taught at a time in one classroom. It is a straight forward way to impart knowledge into students.

vii. It is more helpful for teaching specific facts, concept or laws.

2.4.2 Demerits of traditional method of teaching

As Shulman (1997) categorically pointed out, any educational inquiry possesses some limitations. Tamakloe *et. al.* (2005) pointed out the following disadvantages of the traditional method:

i. Generally, traditional method is not suitable for students who are low on the academic ladder.

ii. Students find it difficult to listen and take notes at the same time.

iii. The traditional method in most cases encourages rote learning.

iv. It does not give the students enough chance to develop their oral skills.

v. Teacher tasks overshadows that of students making them play comparatively passive role in the teaching and learning process.

vi. On the spot feedback is usually very scanty and unreliable.

vii. There is little scope for student activity; hence traditional method goes against the principle of learning by doing.

viii. In the traditional method, the teacher to a large extent spoon feeds the students and does not allow them to develop their powers of reasoning.

Since, science mainly involves activity to help students explore, the traditional method is therefore not the best for solely teaching science. As already stated, the traditional method rather promotes rote learning. Wood (2007) indicated that Biology teachers resort to the traditional method because of the work load. He reported that the enrolment in most science classes is about 50 to 70 students, making it difficult for teachers to resort to the use of more competitive methods. Biology teachers can enrich traditional method of teaching by using more realia, slides and overhead projectors. But the question is how many of our schools are resourced with these technologies?

2.4.3 Effects of traditional method on achievement

Many researchers have compared the traditional method to other methods of teaching in students' achievement. They found out that students normally taught with other methods do perform better than those taught with the traditional method. For instance, Apafo (as cited by Wood, 2007) conducted a study in Cape Coast using 45 males in Senior Secondary School on the topic balancing of chemical equation. The experimental group were exposed to games' simulation approach and the control group exposed to traditional method. He reported that the experimental group achieved significantly higher than the control group. Larbi (2005) also conducted a study in the eastern region of Ghana comparing the indigenous method approach to the traditional method of teaching. He found out that students taught with indigenous method of teaching science achieved significantly higher than those taught with the traditional method. Likewise, Owusu, Monney, Appiah and Wilmot (2010) in their study used 65 students to find the effect of Computer Assisted Instruction (CAI) on students' achievement in Biology. The experimental group were exposed CAIs and control group exposed to traditional method. Cell cycle was the content which both groups were taught. They reported that, students instructed with the traditional method achieved significantly higher than those instructed with computer assisted instruction (CAI).

2.5 Historical Background of Photosynthesis

The history of the origins of photosynthesis forms interesting reading which can give learners a background to this topic. In the early half of the seventeenth century, the Flemish physician van Helmont grew a willow tree in a bucket of soil, feeding the soil with rain water only (Hall, 2004). He observed that after five years the tree had grown to a considerable size; however, the amount of soil in the bucket had not diminished significantly. Van Helmont naturally concluded that the material of the tree came from the water used to wet the soil. In 1727 the English botanist Stephen Hales observed that plants used mainly air as the nutrient during their growth in his book, "Vegetable Staticks". Between 1771 and 1777 the English chemist Joseph Priestley (who was one of the discoverers of oxygen) conducted a series of experiments on combustion and respiration and came to the conclusion that green plants were able to reverse the respiratory process of animals (Hall, 2004). Priestley burnt a candle in an enclosed volume of air and showed that the resultant air could no longer support burning. A mouse kept in the residual air died. A green spring of mint however, continued to live in the residual air for weeks. At the end of this time Priestley found that a candle could burn in the reactivated air and a mouse could breathe in it. We now know that the burning candle used up the oxygen of the enclosed air, which was replenished by the photosynthesis of the green mint. The history captured in this section consists of ideas that learners can debate in order to understand why a green plant would make a difference in the air present in an enclosed container where there is a living small mammal. Such debates in the classroom would also promote language development for learners who are not first language speakers of English. A few years later in 1779, Dutch physician, Jan Ingenhousz, discovered that plants evolved oxygen only in sunlight and also that only the green parts of the plant carried out this process (Hall & Rao, 2004). What has been discussed in this paragraph is history of how some stages in the process of photosynthesis have been discovered. This is part of history of science that is never discussed in many classrooms, but which would give context to what is being studied. This history would help students to understand where science comes from; it would also show that science has a culture. The history of science also shows how different people have collaborated to give us a complete picture of what happens during photosynthesis. It also gives one characteristic of science, that is, it is empirical and consists of knowledge that should be shared among peers. This is unlike indigenous knowledge which is generally not shared openly with peers and this is the culture from which the learners come. In 1782, Senebier, a Swiss minister, confirmed the findings of Ingenhousz and observed further that plants used carbon dioxides dissolved in water as nourishment. Early in the nineteenth century another, Swiss scholar, de Saussure, studied the quantitative relationship between the CO_2 taken up by a plant and the amount of organic matter and O_2 produced and came to the conclusion that water was also consumed by plants during assimilation of CO_2 (Hall & Rao, 2004). In 1817, two French chemists, Pelletier and Caventou, isolated the green substance in leaves and named it chlorophyll. Another milestone in the history of photosynthesis was the enunciation in 1845 by Robert Mayer, a German physician, that plants transform energy of sunlight into chemical energy. By the middle of the 19th century the phenomenon of photosynthesis could be represented by the relationship shown below:

$$CO_2 + H_2O + \text{light} \rightarrow O_2 + \text{organic matter} + \text{chemical energy}$$

Accurate determinations of the ratio of CO_2 consumed to O_2 evolved during photosynthesis were carried out by the French plant physiologist. He found in 1864 that the photosynthetic ratio - the volume of O_2 evolved to the volume of CO_2 used up – is almost unity. In the same year, the German botanist, Sachs (who also discovered plant respiration), demonstrated the formation of starch grains during photosynthesis. Sachs kept some green leaves in the dark for some hours to deplete them of their starch content. He then exposed one half of a starch depleted leaf to light and left the other half in the dark. After sometime, the whole leaf was exposed to iodine vapour. The illuminated portion of the leaf turned dark violet due to the formation of starch – iodine complex; the other half did not show any colour change. These early experiments gave rise to the experiments done in schools where they show that light is necessary for starch to form in leaves.

The direct connection between oxygen evolution and chloroplasts of green leaves, and also the correspondence between the action spectrum of photosynthesis and the absorption spectrum of chlorophyll were demonstrated by the German botanist Engelmann in the 1880. He placed a filament of the green alga Spirogyra, with its spirally arranged chloroplasts, on a microscope slide together with a suspension of oxygen requiring, motile bacteria. The slide was kept in a closed chamber in the absence of air and illuminated. Motile bacteria would move towards regions of greater O_2 concentration. After a period of illumination, the slide was examined under a microscope and the bacterial population counted. Engelmann found that the bacteria were concentrated around the green bands of the alga filament.

2.6 Why photosynthesis is important?

All forms of life in this universe require energy for growth and maintenance. Algae, higher plants and certain types of bacteria capture this energy directly from the solar radiation and utilize the energy for the synthesis of essential food materials. Mader

(2004) states that life on earth is solar powered. The chloroplasts of plants capture light energy that has travelled 160 million kilometres from the sun to convert it to chemical energy stored in sugar and other organic molecules. Described accurately plants should be called photoautotrophic because they use light as a source of energy to synthesize organic substances. During photosynthesis, carbon dioxide is absorbed and oxygen released. Oxygen is required by organisms when they carry on cellular respiration. According to Campbell and Reece (2005) oxygen released in photosynthesis also rises in the atmosphere and forms the ozone shield that protects terrestrial organisms from the damaging effects of the ultraviolet rays of the sun. Animals cannot use sunlight directly as a source of energy; they obtain the energy by eating plants or by eating other animals which have eaten plants. Thus, the ultimate source of all metabolic energy in our planet is the sun, and photosynthesis is essential for maintaining all forms of life on earth (Hall & Rao, 2004).

2.7 Why learners seem to show less interest in photosynthesis?

Plants sciences are generally poorly represented in high schools and undergraduate courses (Hershey, 2002). They often receive poor responses, especially from students enrolled in biomedical type course. Students complain that plants sciences are boring. Looking at the central role of the process in Biology, teachers struggle, nevertheless, to promote the relevance and importance of photosynthesis to their students. Photosynthesis is also a conceptually difficult topic, which spans several disciplines like Biophysics, Biochemistry, Ecophysiology and Organizational levels including molecules, cells, organisms and ecosystem. Because of these problems of relevance and difficulty, major misconceptions often persist in students understanding of photosynthesis. Learners seem to be bored when learning about plants because they feel photosynthesis is too abstract. The researcher concurs with Sharon, Gurdal and

Ave-Berkem (2004) because learners have a tendency of wanting to learn about something that is interesting in a way that they apply in their daily lives. Even though photosynthesis is a daily thing it is a natural and automatic process that has not much to do with them. Students fail to understand that the cereal they consume for breakfast is a product of photosynthesis. An end to photosynthesis would probably mean death to all living organisms.

Hence learners seem to show less interest in photosynthesis because it a conceptually difficult topic to comprehend, very abstract, as the instructors often fail to let the students visualize the process that go on with the process of photosynthesis.

2.8. Challenges in teaching photosynthesis

One of the fundamental challenges of teaching in areas such as Biochemistry and Biophysics is that, these areas involve the comprehension of objects and process that cannot be seen or experienced. Topics that are taught in biochemistry includes structure and functions of proteins, membrane, electron transport and light harvesting from indirect observations using measuring systems and analytical methodologies, which a lot of biology teachers, without a solid chemistry background skip the biochemistry topics that would lay a foundation to understand photosynthesis.

Knowledge about the nature of these invisible entities evolves, punctuated by controversy and consensus about the actual structure and the characteristics that define them. Regardless of the sophistication of our understanding as teachers, and its fit with empirical data, we visualise these objects and process using imagination, models and metaphors. Our challenges in teaching are how to communicate our vision of objects and process in such a way that we generate understanding and excitement while avoiding misconceptions. Pedagogical content knowledge (PCK) is important in teaching difficult topics like photosynthesis. It is a concept introduced by Shulman (2000) who started that different topics require very different ways of being taught if they are to be understood. There is the need for new teaching materials and approaches that present photosynthesis in all its complexity, but in a way that stimulates the interest and excitement of students and promotes deep and accurate understanding. According to Moore and Miller (2006), multimedia has the potential, in combining written and spoken word with dynamic pictures and models, to bring abstract concepts and invisible objects and process to life, and to do so in a flexible and reliable way which increases retention and learning. The interactive, user friendly format and excellent graphics, models and animation should improve students' satisfaction and attention, and their learning outcomes. The problem of learners in rural and other poverty-stricken areas is lack of proper resources to enhance learning as well as poorly trained educators who reinforce misconceptions because of their poor understanding of the subject's content. Combination of written and spoken word with dynamic pictures, models and animations should suit a range of students and learning styles, including the visually oriented (Beakes, 2003). In spite of less interest in learners, educators need to be very innovative so as to arouse learner's interest. Educators need to develop their strengths in teaching photosynthesis through changing learner attitudes. Educators need to try learner centredness where possible in teaching photosynthesis so that learners will own the self-discovered knowledge and also have interest in developing it while educators present it. We can use innovative teaching methods like the use of models and animation to help students understand the process of photosynthesis.

2.9 Students Misconceptions about Photosynthesis

Photosynthesis is often de-emphasized in Biology curricular, because of the tendency to focus on plant, rather than animal process. Conceptual challenges of understanding this multi–faceted process including electron transport, factors affecting photosynthesis and carbon dioxide fixation is also a problem in understanding this whole process. Russel, Robinson and Netherwood (2001) and a number of authors are supporting the statement that, major misconceptions often persist in students 'understanding of photosynthesis (Haslams & Treagust, 2007). According to Heshey (2002), in his article entitled "Avoid misconceptions when teaching about plants". Other misconceptions are: The 'dark reactions' of photosynthesis are a misnomer that often leads students to believe that carbon fixation occurs at night. It is better to use the Calvin Cycle. Plants get most of their food from the soil (that is why they need fertilizer), not from the sun. Photosynthesis is the simple conversion of CO_2 and water to carbohydrates and O_2 regardless of stages involved. Plants photosynthesize during the day and respire at night. Chlorophyll molecules in the light harvesting complexes transfer excited electrons to the reaction centre. Plants are green because they absorb green light. Robinson (2004) states that these major misconceptions, students may become familiar with words and descriptions of process such as electron transport, light harvesting, oxygen evolution and carbon fixation, but may have only very shallow, and in some cases, flawed understanding of what these processes really mean. Although they may be able to develop these concepts sufficiently to pass exams in early years of school, their literacy in this area is likely to remain at a low level (Uno & Bybee, 2004), and they may have to unlearn and relearn this material at higher levels as flaws in their understanding begin to compromise their progress in this area (Robinson, 2004). This is usually seen in students who learn in a foreign language and not in their mother tongue. Memorization of the terms does not mean conceptual understanding. The researcher feels that photosynthesis need to be taken step by step by introducing it at an early stage of education so that learners get deeper understanding with it as they progress to higher levels of education. It is hoped that at their learning levels they will have clear understanding of concepts and terminologies. By so doing we will be promoting students with deeper insight in Biology, particularly in complex topics like photosynthesis.

2.10 Overcoming Learners' Misconceptions

In recent years many scientific researchers have focused on the student's comprehension of scientific concepts. It was determined in these studies that, student's constructions of a concept on a subject are different from the experts of that subject. The students' different perceptions of the concepts have to be dealt with in a manner known as 'Conceptual Change Approach' to remove the misconceptions. According to the Conceptual Change Approach, which was developed by Sahin, Guarda and Ave-Berkem (2000), the concepts should be comprehensible and logical to remove the students' misconceptions. However, taking into account the fact that the scientific concepts are mostly abstract and this field has microscopic facts, the perception of these concepts by the sense organs are limited. For this reason, the students' realization of the scientific concepts and events in their mind is important to make the scientific concepts comprehensible and logical. In science education, meaningful learning can be obtained by using analogies to teach the concepts and events that are difficult to understand. However, sometimes analogies are also limited and may introduce other misconceptions. Meaningful learning depends on the success of creating and finding relationships between pre – knowledge and newly learned content and one of the ways of finding such relationships is to create and use the analogies (Sahin et.al., 2000). Science concepts can be taught better by using similar events that people meet in daily life e.g., watching a video player. When the active participation of the students is secured and the connection between the analogy and the behavior is set, students' misconceptions are reduced (Silverstein, 2000). The analogies are generally classified into two groups as individual and visual analogies. In individual analogies the student has an active role and realizes these events in his/her mind. In visual analogies, the concepts which are difficult to understand are tried to be comprehended by students through using some diagrams and pictures, which are mostly accompanied by oral explanations. This type of analogy helps students making resemblances between pictures and the concepts. Analogies are the most important tools, which accelerate conceptual change in scientific judgment in learning and teaching (Duit, 1991). Instead of giving them handy analogies, the students' creation of their own analogies makes the conceptual changing process of the students most useful (Wong, 2003). Sahin et. al., (2000) emphasized that for developing analogies the students should also have adequate knowledge about the analogies and individual talents which are effective to develop analogies. In addition, developing analogy requires both the desire and capability to do so.

2.11 Who should be taught and what aspect of photosynthesis?

Science national curriculum for England states that all pupils aged 11–14 should be taught that plants need carbon dioxide, water and light for photosynthesis, and produce biomass and oxygen (Haslam & Treagust, 2007). The syllabus also states that the students should also know that: photosynthesis can be summarized as a word equation- nitrogen and other elements, in addition to carbon, oxygen and hydrogen, are required for plant's growth. Pupils at this age are also taught that plants carry out aerobic respiration. These ideas are revisited between the age of 14 and 16 in slightly more details. At this stage the curriculum states that pupils should be taught “The reactants and products of photosynthesis”, for instance:

i. how the products of photosynthesis are utilized by the plant.
ii. the importance to healthy plant growth of the uptake of mineral salts.
iii. in addition, they should be taught that the rate of photosynthesis may be limited by light intensity, carbon dioxide concentration and temperature.

Because of the overlapping of the curriculum between ages 11 to 14 and 14 to 16, it was possible to design a teaching sequence which could be used across both age ranges (Haslam & Treagust, 2007). This is the reason for choosing the senior high school of the age range between 14 - 18 since their syllabus include the topic photosynthesis. In the West African School Certificate Examination (WASCE) syllabus, the Ministry of Education requires the learners to study:

i. the process of photosynthesis, a simple outline
ii. practical investigation of the – starch test.
iii. factors that influence photosynthesis – practical investigation of light, chlorophyll, carbon dioxide, oxygen, temperature and water.
iv. the two phases of the process of photosynthesis i.e., the light phase and dark phase.
v. the products of photosynthesis.

Whitmarsh and Govindjee (2005) on their website on high school Biology lesson plan give a very simple outline of what high school students should be taught on photosynthesis. The work covered is as follows:

The authors first stated that at the end of the study the learners should be able to:

i. describe the energy transformations that occur in a chloroplast as light energy is converted to the chemical bond of energy of carbohydrate.
ii. draw a sketch of a chloroplast and indicate where these energy transformations take place.
iii. list the inputs (raw materials) and outputs (products) of the light reactions and the Calvin Cycle.
iv. describe the role of enzymes in the process of photosynthesis.
v. explain what the plant does with the carbohydrate that is produced by photosynthesis.

Secondly, the authors put a brief outline of the areas one needs to deal with in teaching about photosynthesis. These topics are shown as:

1. Chloroplast Structure:

i. Outer membrane
ii. Inner membrane systems
iii. Thylakoid membranes
iv. Thylakoid space (within the thylakoids)
v. Granum a stack of thylakoid membranes
vi. Stroma (the liquid area outside the thylakoid membranes)

2. The Photochemical Light Reactions:

i. Capture of light energy
ii. Thylakoid membranes

iii. Photosystems II and I

iv. Chlorophyll and accessory pigments.

3. Light absorbance and Photosynthesis:

i. Energy transformations

ii. Flow of Electrons

iii. Splitting of water molecules Release of oxygen

iv. Accumulation of H+ in thylakoid spaces

v. Reduction of NADP to NADPH

vi. Production of ATP

vii. ATP synthase

viii. ADP + Phosphate = ATP

4. The Biochemical Reactions: The Calvin Cycle:

i. "Fixing" CO_2

ii. Cyclic series of enzyme reactions Ribulose phosphate (the enzyme that fixes CO_2)

iii. Stoma and CO_2 availability

iv. Addition of CO_2 to a 5-carbon compound

v. Production of Carbohydrates

vi. Energy input from ATP

vii. Addition of H+ and energy

viii. Production of carbohydrates for storage, transportation, and biosynthesis

ix. Recycling of 5 carbon compound to fix more CO_2.

Many teachers are poorly qualified and have problems understanding at what depth they should be teaching. The outline presents a very good example of what concepts teachers at high school level should be unpacking with the learners. Looking for such material also helped the research to reflect at how she has taught the topic and how she could enrich future teaching by giving learners a holistic picture of the process.

2.12 Students' Perceptions on Photosynthesis

A review of the literature on teaching and learning about plant nutrition was conducted by (Driver & Barker, 2003). The following characteristic patterns in students reasoning were identified:

i. a view of nutrition, based on animal nutrition, as the ingestion of 'food' and the idea that food' is absorbed from the soil through the roots of a plant.
ii. a lack of differentiation between photosynthesis and respiration (the idea that photosynthesis in the plant is equivalent to respiration, that sugar provides energy not biomass).
iii. the idea that sunlight is a reagent, not a source of energy. A lack of recognition of the chemical basis of biological process, and those simple ingredients such as water and carbon dioxide can be combined (through chemical reactions) to produce more complex materials.
iv. a difficulty in accepting that gases can be a source of biomass.
v. a lack of recognition that mass/matter is conserved in biological process.
vi. a lack of recognition of the site of biological process within an organism.

2.13 Learning Cycle Model

Learning cycle was designed to promote scientific understanding and thinking abilities among students (Lawson & Snitgen, 1982; Saunders & Shepardson, 1987; Schneider & Renner, 1990; Marek & Methven, 1991; Guzetti, Snyder, Glass, & Gamas, 1993; Marek & Cavallo, 1995; Lavoie, 1999). To this end, it is the one predominant teaching method that has long histories of use and remain widespread in the science education community (i.e., Renner, 1986; Bergquist, 1991; Marek and Methven, 1991; Trifone, 1991; Gang, 1995; Abraham, 1998; Lawson, 2000; Odom and Kelly, 2001).The learning cycle was developed by Karplus (1977), but it is not right to say who first invented the learning cycle because the learning cycle is one method of teaching which purports to be consistent with the way people spontaneously construct knowledge. In other words, anyone who has reflected upon how to teach effectively has no doubt discovered aspects of the learning cycle (Lawson et.al., 1989). At first hand, the learning cycle was formally introduced for elementary-age students as a part of Science Curriculum Improvement Study (1974). However, it was later adapted for a wide variety of grade levels and topics (Purser & Renner 1983; Saunders & Shepardson 1987; Stepans, Dyche, & Beiswenger, 1988; Zollman, 1990; Barman, 1992; Barman, Cohen & Shedd 1993; Allard & Barman, 1994).

The learning cycle brings a unique epistemology to learning and have proven to provide a better understanding of the learner and the learning process (Odom & Kelly, 2001). Learning cycle is deeply rooted in Piaget's developmental theory, but it also embodies other constructivist paradigms of learning and development. These paradigms include Vygotsky's (1978) social constructivist theory and Ausubel's (1963) meaningful learning theory (Marek, Gerber & Cavallo, 1999). Scaffolding, for example, is used throughout the learning cycle. Also, in the learning cycle classroom, teachers work within each student's zone of proximal development toward attaining new levels of development. Moreover, because of the students' active role in the learning process, the learning cycle promotes the use of students' meaningful learning strategies as opposed to rote strategies (Marek, Gerber & Cavallo, 1999). Especially, learning cycles promote a meaningful learning by providing application activities that help students link their understanding of the concept to other experiences in science and in everyday life (Ausubel, 1963). Originally, Karplus and Thier (1967) determined three distinct phases for the learning cycle, named as exploration-invention-discovery (Abell & Lederman, 2007). More recently, these phases have been referred to as explore, explain, and expand (Trowbridge & Bybee, 1990) and to exploration, term/concept introduction or invention, and concept application (e.g., Renner, Abraham, & Birnie, 1988; Lawson, 1995; Marek & Cavallo 1997; Sunal & Sunal, 2000) with slightly different terms being used by the different authors (Dwyer & Lopez, 2001). Basically, a three-phase learning cycle approach is based on the Piagetian notions of learning new concepts through assimilation and disequilibration in the first phase, accommodation in the second phase, and conceptual expansion in the third phase (Lawson, 1995; Renner & Marek, 1990; Abell & Lederman, 2007). Learning cycles begin with an exploration where students learn through their own actions and reactions as they explore new materials and ideas (Maier & Marek, 2006). During this phase, students are involved in scientific processes such as, measuring, observing, experimenting, gathering data and interpreting data related to a particular science concept. The concept and related terminology are not provided to students; instead, the teacher provides appropriate experiences and acts as facilitator (Cavallo, McNeely & Marek, 2003). Also, this phase provided an opportunity for students to begin to develop the declarative and procedural knowledge with the development of their hypothesis creation and testing skills (Odom & Kelly, 2001). Ideally, exploration should confront students with new information that will cause them to think about how the data or experience they encountered fit with what they already know (Rule, 1995; Maier & Marek, 2006). If a student can account for the data based on prior knowledge assimilation has occurred. During assimilation, observations or experiences are accounted for by students' existing knowledge (Maier & Marek, 2006). However, if new concepts do not fit in with old ideas, this leads to a questioning of old thinking patterns and disequilibrium occurs (Rule, 1995). Following the exploration is the concept/term introduction, when students analyze and interpret the newly collected data. This second phase of the learning cycle is designed to allow students to re-equilibrate and accommodate the new concept (Maier & Marek, 2006). In this phase, students are in the accommodation, because they make their own meaning out of the observations. Here, students either achieved to make adjustments in each mental structure to make it fit their experience, or they do not construct the new mental structure and then fall in disequilibrium phase again (Türkmen & Usta, 2007). During this phase, the teacher uses textbooks, audiovisual aids, other written materials, or mini-lectures (Allard & Barman, 1994). Although the teacher takes an active role in presenting the concept, this phase should not take on the form of a lecture. Instead, students are guided by the teacher in a discussion designed to let them interpret the newly collected data. Students arrange and report their group data so that they can formulate hypotheses for the phenomenon under examination (Maier & Marek, 2006). Moreover, appropriate scientific language and terminology should be provided during this phase (Heard & Marek, 1985).

2.14 5E Learning Cycle Model

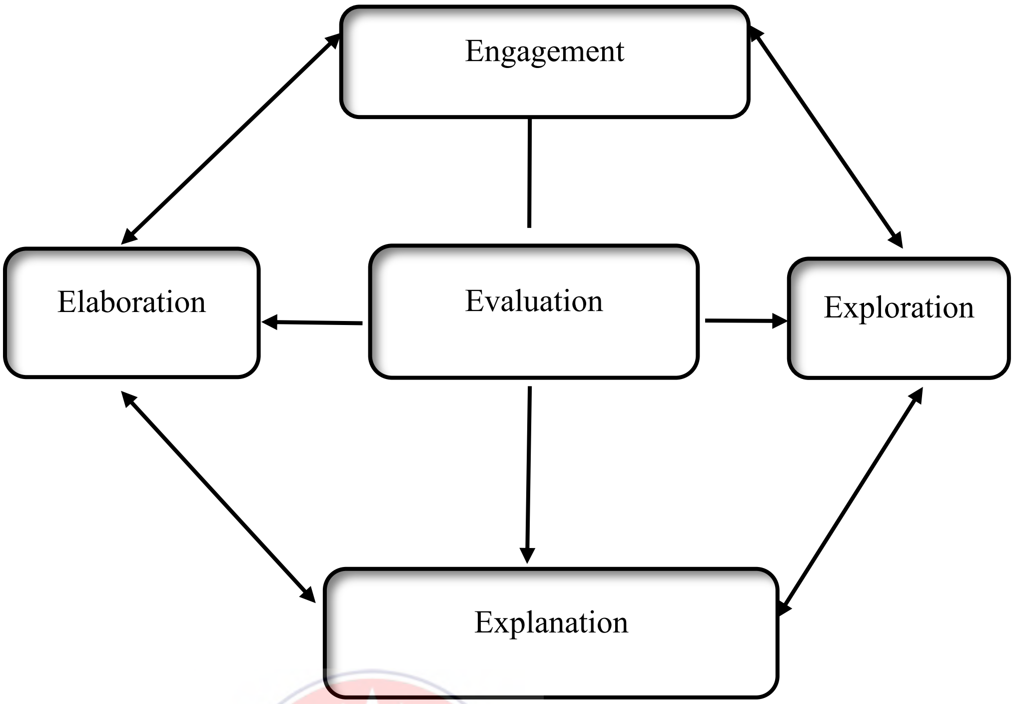

Figure 1: The 5E Instructional Model: Adapted from Duran (2003)

The 5E instructional model, as outlined in figure 1, was developed in the late 1980's as a component of the Science for Life and Living curriculum created through the Biological Sciences Curriculum Study (BSCS) (Bybee & Landes, 1990). This model is rooted in constructivism and it is accepted as an instructional approach that supports inquiry-based science learning in a classroom setting (Bybee & Landes, 1990; Wilder & Shuttleworth, 2005). The main objective in a constructivist program is to challenge students' current conceptions by providing data that conflict with students' current thinking or experiences that provide an alternate way of thinking about objects and phenomena (Bybee & Landes, 1990). To this end, the 5E model meets these conditions for conceptual change by having students redefine, reorganize, elaborate, and change their initial concepts through self-reflection and interaction with their peers and their environment (Bybee, 1997). Since 1980's, BSCS has used 5E

Instructional Model extensively in the development of new curriculum materials and professional development experiences. The "Five E" Learning Cycle model consists of five phases called as; Engagement, Exploration, Explanation, Elaboration and Evaluation, and each phase has a specific function and contributes to the teacher's coherent instruction and to the learners' formulation of a better understanding of scientific and technological knowledge, attitudes, and skills (Bybee, Taylor, Gardner, Scotter, Powell, Westbrook, & Landes, 2006). The engagement phase is used to motivate students by creating some mental disequilibrium or tapping into familiar real–life situations. Typically, this is done with activities, demonstrations, or stories that grab students' attention and help them make connections between the new information and the world they know. Asking questions and posing a problem may be included in the engagement activities. Here, the word "activity" refers to both mental and physical activity. The instructor's role in this phase is to raise questions and problems, create interest, generate curiosity, and elicit responses that uncover students' current knowledge (Bybee, 1997; Carin & Bass, 2000). This phase also gives a good opportunity for the teacher to identify students' misconceptions. Quite possibly, this is the most critical phase of the model; if the material is not presented well, students may not make the necessary associations to fully interact with the topic and the remaining phases become meaningless (Campbell, 2000). Once students are engaged in the learning tasks, exploration activities follow. Indeed, engagement phase brings about disequilibrium, and exploration initiates the process of equilibration (Bybee *et. al.* 2006). Exploration activities are designed so that the students in the class have common, concrete experiences upon which they continue formulating concepts, processes, and skills (Bybee, 1997). During the Exploration stage, the teacher should facilitate safe, guided or open inquiry experiences and questioning so students might uncover their misconceptions about the concept (Bybee, 1993; Wilder & Shuttleworth, 2005). Also, students should be given opportunities to work together without direct instruction from the teacher. This is the opportunity for students to test predictions and hypotheses and/or form new ones, try alternatives and discuss them with peers, record observations and ideas and suspend judgment. In this phase, students interact directly with the material concepts, or phenomenon. The teacher's role during this phase is that of a facilitator as he/she encourages cooperative group discussions by asking guiding questions and serves as a resource for students. In a study conducted by Lindgren and Bleicher (2005), preservice teachers who were learning the learning cycle found this stage to be central to the process as they were able to "explore, discover, investigate, and act like a scientist" during this phase. Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation. The explanation phase focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase provides opportunities for teachers to directly introduce a concept, process, or skill. Most teachers recognize the explain phase as "lecturing" or interactive discussion, where teachers give students information, they may not be able to glean on their own. At the beginning of the explanation phase, students are encouraged to provide their explanations from events during the explore phase (Bybee, 1997). Students should use observations and recordings in their explanations. In addition to simply providing their own thoughts, students are also expected to listen critically to other students' explanation and those of the teacher. At this stage teacher help students understand scientific explanations and introduce terminology to provide students with a common language about the content (Bybee, 1993). The teacher connected the scientific explanation with the physical evidence from exploration and engagement and relates it to the explanations that the children have formed. Here, verbal methods are mostly used, but the teacher might also use videos, books, multimedia presentations, and computer courseware. This phase continues the process of mental ordering and provides terms for explanations. In the end, students should be able to explain exploratory experiences and experiences that have engaged them by using common terms. In the elaboration phase students are encouraged to extend their understanding of a scientific concept past what they have experienced through the previous three phases. During this phase, students should apply concepts and skills in new, but similar situations and use formal labels and definitions. Remind students of alternative explanations and to consider existing data and evidence as they explore new situations. Bybee (1997) stated the primary goal of the elaboration phase as the generalization of concepts, processes, and skills. To achieve this goal, additional problems are given to students, which allow them to apply their new knowledge, propose solutions, make decisions and/or draw reasonable conclusions, and teacher encourages students to use formal science terms as they complete related activities and identify alternative ways to explain phenomena. Those who still hold misconceptions or have not yet achieved dissatisfaction with their current ideas may be able to clarify their perceptions through this extension of learning (Bybee, 1997). In brief, the elaboration phase of the 5E model allows students to apply knowledge they have gained to new situations so they can expand their conceptual understanding and skills (Bybee, 1993). The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives. Although evaluation presented as a final stage of the 5E model, it should take place at each stage of the instructional unit. Evaluations should focus on students' conceptual understandings, skills development or other learning outcomes. This may be done formally or informally. Appropriate assessment strategies might include performance assessments, evaluation of drawings or physical models made by students, interviews with groups of students or individuals; creative writing exercises using science concepts, creation of concept maps by students, or examination of student laboratory notebooks or portfolios. To sum up, this phase is essential to determine if students obtained a scientifically correct understanding of the concept and if they were able to generalize to other contexts. Students should assess their own learning. Table 1 showed the salient characteristics of each stage of the 5Es. To develop this table, we benefited by several studies (Carin & Bass, 2000; Bybee *et. al.*, 2006).

The 5E learning cycle-based instruction was developed by the Biological Sciences Curriculum Study (BSCS) in 1989. It consists of 5 phases: Engagement, Exploration, Explanation, Elaboration and Evaluation.

i. **Engagement:** In this phase, activities that initiate students' curiosity are made. These activities help students to make connections with the previous knowledge. Asking questions and posing a problem may be included in the engagement activities.

What the teacher does consistent with this model:

a. creates interest.

b. generates curiosity.

c. raises questions.

d. elicits responses that uncover what the students know or think about the concept/ topic (Carin & Bass, 2000).

What the student does consistent with this model:

a. asks questions such as: "Why did this happen?", "What do I already know about this?", "What can I find out about this?"

b. shows interest in the topic (Carin & Bass, 2000).

ii. **Exploration:** Once students are engaged in the learning tasks, exploration activities follow. In exploration, students observe properties, form simple relationships, note patterns and raise questions about events to develop fundamental awareness of the nature of materials and ideas. They have the opportunity to get directly involved with phenomena. The teacher's role in the exploration phase is that of guide, coach and facilitator.

What the teacher does consistent with this model:

a. encourages students to work without direct instruction from the teacher.

b. observes and listens to students as they interact.

c. asks probing questions to redirect students' investigations when necessary.

d. provides time for students' investigations when necessary.

e. provides time for students to puzzle through problems.

f. acts as a consultant for students (Carin & Bass, 2000).

What the student does consistent with this model:

a. thinks freely, but within the limits of the activity.

b. tests predictions and hypotheses.

c. forms new predictions and hypotheses.

d. tries alternatives and discusses them with others.

e. records observations and ideas.

f. suspends judgment. (Carin & Bass, 2000, p.120-121)

iii. **Explanation:** In this phase, teachers help students make sense of their observations and the questions that arise from their observations. The teacher asks children to describe what they see and give their own explanations of why it happened. Then, the teacher introduced a scientific explanation for the event through formal and direct instruction. The teacher connected the scientific explanation with the physical evidence from exploration and engagement and relates it to the explanations that the children have formed. Verbal methods are most common here, but the teacher might also use videos, books, multimedia presentations, and computer courseware.

What the teacher does consistent with this model:

a. encourages students to explain concepts and definitions in their own words.

b. asks for justification (evidence) and clarification from students.

c. formally provides definitions, explanations and new labels.

d. uses students' previous experience as the basis for explaining concepts (Carin & Bass, 2000).

What the student does consistent with this model:

a. explains possible solutions or answers to the others.
b. listens critically to one another's explanations.
c. questions one another's explanations.
d. listens to and tries to comprehend explanations offered by the teacher.
e. refers to previous activities.
f. uses recorded observations in explanations (Carin & Bass, 2000).

iv. **Elaboration:** In this phase new experiences are designed to assist children in developing broader understandings of the concepts already introduced. Students expand on the concepts they have learned, make connections to other related concepts, and apply their understanding to the real world around them. Children work in cooperative groups, identify and complete new activities. It often involves experimental inquiry, investigative projects, problem solving and decision making. Lab work is common. Small-group and whole-class discussions provide students opportunities to present their own understandings. By observing the students in this phase the teacher may decide to recycle through the different phases of the 5E learning cycle to improve children's understanding or move onto new science lessons.

What the teacher does consistent with this model:

a. expects students to use formal labels, definitions, and explanations provided previously.
b. encourages students to apply or extend the concepts and skills in new situations.
c. reminds students of alternative explanations.

d. refers students to existing data and evidence and asks: "What do you already know?" "Why do you think…?"(Strategies from Explore apply here also.) (Carin & Bass, 2000).

What the student does consistent with this model:

a. applies new labels, definitions, explanations, and skills in new, but similar, situations.
b. uses previous information to ask questions, propose solutions, and make decisions, design experiments.
c. draw reasonable conclusions from evidence.
d. records reasonable conclusions from evidence.
e. records observations and explanations.
f. checks for understanding among peers (Carin & Bass, 2000).

v. **Evaluation:** Evaluation and assessment occurs at all points along the continuum of the instructional process. Rubrics, teacher observation structured by checklists, student interviews, portfolios designed with specific purposes, project and problem-based learning products, concept maps and roundhouse diagrams may be used to assess students' understanding of concepts. The roundhouse diagram is learning tool proposed by Wandersee in 1985. It is a two-dimensional geometric figure, which has a circular shape with seven sectors. The seven sectors are based on the study of Miller (1956) who determined that most people can effectively recall seven items, plus or minus two. The roundhouse diagram allows the teacher to visualize a student's mental representation of what is already known (Trowbridge & Wandersee, 1998). By using this tool, the teacher can detect students' misconceptions and correct the inaccurate conclusions. Roundhouse diagrams may be used as a tool in the evaluation part. By using these tools teachers observe students as they apply new concepts and skills to assess students' knowledge and/or skills, looking for evidence that the students have changed their thinking or behaviors. The opportunity to allow students to assess their own learning and group-process skills is often provided.

What the teacher does consistent with this model:

a. observes students as they apply new concepts and skills.
b. assesses students' knowledge and/ or skills.
c. looks for evidence that students have changed their thinking or behaviors.
d. allows students to assess their own learning and group process skills
e. asks open-ended questions, such as: "Why do you think….?", "What evidence do you have?", "What do you know about x?" How would you explain x?" (Carin & Bass, 2000).

What the student does consistent with this model:

a. answers open-ended questions by using observations, evidence, and previously accepted explanations.
b. demonstrates an understanding or knowledge of the concept or skill.
c. evaluates her own progress and knowledge.
d. asks related questions that would encourage future investigations (Carin & Bass, 2000).

2.15 Research Studies on 5E Learning Cycle and Achievement

Studies show that 5E Learning Cycle approach had a positive effect on students understanding (i.e., Colburn & Clough, 1997; Bevenino, Dengel & Adams, 1999; Lord, 1999), scientific reasoning (Boddy & Aubusson, 2003), and attitudes toward science (Boddy & Aubusson, 2003; Akar, 2005). For example, Lord (1999) conducted a study that compared two classes taught by traditional methods with two classes taught with 5E Learning Cycle method. 5E Learning Cycle method used involved small heterogeneous groups who worked on thought provoking scenarios and critical thinking questions or constructed concept maps. The results indicated that the experimental groups had much greater understanding of the information covered especially on questions that required interpretation. Also, a significant difference was found in the feedback from the students. Most of the experimental group students wrote positive comments about the course. However, about half of the students in the control group only wrote any response, and of the comments that were written few were positive. Study performed by Campbell (2000) investigated the fifth grade students' understanding of force and motion concepts through the use of the 5E learning cycle. Students participated in investigations about force and motion concepts weekly for a period of 14 weeks. Findings showed that students' knowledge about force and motion concepts increased although their knowledge as demonstrated on paper was insufficient. It seemed that the students were of the same opinion that learning science through text book was not the best way for them.

The aim of the study conducted by Ozsevgec, Cepni and Bayri (2007) was to discover the effectiveness of the 5E model on 5th grade students' constant conceptual changes. The researcher developed the 5E learning activities based on the 'Force and Motion' unit's objectives. It was noticed that although there were no differences between the initial conceptual level of the experiment and control group students before 5E learning cycle, after the application, treatment group students were better at having conceptual changes than the students in the control group. However, the difference was remarkable between the pre-test and post-test scores, on the other hand, we did not see much important changes between the post-test and retention test scores in the students of treatment group. As a conclusion, 5E model was more effective in changing students' attitudes than traditional instruction. Ozsevgec (2006) investigated the effect of 5E learning cycle on 5th grade students' achievement and attitudes toward science and technology course. It was found that there was a statistically significant mean difference in the favour of 5E learning cycle group. In another study performed by Lee (2003), in his lesson of plant nutrition which was prepared according to learning cycle during 10 years, provided from 5E learning cycle to make the lesson more real by using real plants as well as pictures and figures. In this way, students were in an interaction with each other with small groups and in the level of all classrooms. Eventually, the students were provided to acquire knowledge about the plants in daily life and also to understand the concepts better. Study performed by Whilder and Shuttleworth (2004) investigated in the effectiveness of 5E learning cycle in "Cell Inquiry". The participants of the study consisted of high school students in the lesson of Biology-1. In the start of study, students were provided to rethink what they learned and knew and were made to be motivated. In the phase of exploration, the students were faced with everyday life situations but in the phase of explaining, the teacher led students to explain their own results scientifically. In the sequence of extension, the students were given more problems and different problems, and in the sequence of evaluation, they wanted to see if the students developed a true understanding on the concepts. Saygin, Atilboz and Salman's (2006) studies were carried out by students in classes. In the classes in which constructivist teaching approach was applied, Rodger Bybee's 5E model was used. The tests were applied to students as pre-test and post-test. It was reported that, the students who studied with constructivist teaching approach were more successful than the ones who studied with traditional method in learning the cell subject. Balci (2005) studied photosynthesis and respiration in plants with 8^{th} grade students. In the first experimental group, the classes were assigned according to the 5E learning cycle and in the second one, the classes were assigned according to the conceptual change text-based instruction. As for the control group, the traditional teaching method was applied. Two-tier multiple choice diagnostic test was applied to all test groups as pre-test and post-test. The results show that the students of experimental group were more successful. Moreover, the methods applied in the experimental groups were impressive in eliminating the students' misconceptions.

In other study effectiveness of 5E learning cycle on 8th grade students' achievement on photosynthesis and respiration in plants was investigated by Cakiroglu (2006). Students' knowledge on photosynthesis and respiration in plants was determined by a test developed by Haslam and Treagust. This test was applied to 67 eight-grade students in two classes of the same elementary school as pre-test and post-test while the experimental group students (n=33) learned the lesson by 5E learning cycle instruction, control group students (n=34) learned the lesson by traditional instruction. The significant difference was found between the experimental and control groups in favor of 5E learning cycle instruction. Another research conducted by Lord (1999) compared 5E learning cycle instruction with the traditional instruction in environmental science course by choosing two control and two experimental groups which consisted of college undergraduates. Each group was given environmental science class by the instructor for 90 minutes 2 times a week. Data was collected by using polls, determining student ideas with 3 multiple-chosen exams composed from 50 questions. As a result, it was seen that experimental group's approximate test scores were higher than the control group. In the questions about remembering the knowledge, both groups got nearly the same scores. But in the questions about interpreting, analyzing and thinking critically, the control group students showed lower performances. Cardak, Dikmenli and Saritas (2008) aimed to investigate that the effect of the 5E learning cycle on sixth grade students' achievement during the circulatory system unit. While the experimental group and the control group were the same at first, after implementation, there was an important difference in favour of the experimental group. The study performed by Demircioglu, Ozmen and Demircioglu (2004) was based on the 5E, which was instructional model for the constructivist view of learning, about the topic "Factors Affecting the Solubility Equilibrium" in lycee-2 chemistry curriculum. It was noticed that experimental group students were more successful than the other group. Because in the experimental group, the activities used were based on 5E learning method. Moreover, the students' opinions were taken into consideration. Yildirim, Er Nas, Senel and Ayas (2007) expressed the aim of their study to discover 7th grade students' misunderstandings about dissolution and melting and solution them via activities designed based on the 5E learning cycle. At the beginning of the study, a concept test was implemented as a pre-test. According to the results of the test, an activity was developed based on the 5E learning cycle. The teacher implemented the activity regularly in the period of the lesson. After two weeks passing, pre-test was implemented as post-test. Finally, three students played role in the semi-structure interviews that was conducted. At last, it was pointed out that the activity designed according to the teaching model affected students in a positive way in remediation of students' misunderstandings about dissolution and melting. Orgill and Thomas (2007) suggested that analogies could be useful tools in each phase of the 5E learning cycle and pointed out that science classes would provide from performing the lesson with the challenging concepts that were related to everyday experiences. They gave examples about what the students and teachers could do while using analogies in each phase.

2.16 Educational Implications for the Science Teacher

On the basis of the findings of the present work, the underlisted educational implications could be offered.

A lot of Biology concepts are abstractive in nature which makes understanding very difficult. Prospective science educators should therefore be given the chance to apply their understandings about 5E LCM based on constructivist approach through in-service education and training.

Science educators should employ instructional strategies that facilitate students' understanding such as: 5E LCM based instruction, since, TI (lecture method) is of less effective than 5E learning cycle-based instruction. The spreading of the use of 5E LCM activities, learners' perception that science courses such as Biology are learned by rote memorization can be curtailed. The harbouring of misconceptions can be prevented by providing concrete examples for the applications of 5E LCM tasks in real life, and by creating and working with smaller groups.

Science instructors should be in the known of students' attitudes and behavior towards Biology since it impacts learners' achievement and should diagnose innovative, effective and efficient learner-centered and activity-oriented instructional methodologies that could improve learners' attitudes and performance.

Learners should also be provided with the opportunities to carry out researches, formulate hypotheses, analyse and interpret their results, and to create their own knowledge and understanding; to facilitate their science process skills acquisition and better comprehension of Biology concepts and terminologies.

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter deals with the research methodology employed in the study. It discusses the study area, research design adopted for the study, population sample and sampling procedures used in the study. The data collecting, instruments, and their validity and reliability, data collection procedure, procedure for data analysis have also been presented in this chapter. The study was done in Adukrom Senior High Technical School.

3.1 Research Design

The study employed the quasi-experimental research design. This study employed pre- and post-tests only non-equivalent control group design of the quasi-experimental research design. Such a design was used because the study used intact classes which did not permit random selection and assignment of participants. Posttest only non-equivalent control group design of quasi-experimental design was also used because the study investigated the effect of two teaching approaches: 5e learning style approach and the traditional teaching approach, on experimental and control groups (students), which have not been equated by randomization (Cohen, Manion & Morrison, 2008) in SHS 3 in Adukrom Senior High Technical School in the Eastern Region of Ghana.

3.2 The Study Area

The study area for this research study was a public Senior High Technical School (ASHS). The school is located at Adukrom, the capital of Okere district. The school has a student population of 2563 and 75 teachers. As a mixed system school, it runs all the second cycle programmes – General Arts, Visual Arts, General Science, Agriculture Science, Home Economics, Business and Technical. Adukrom is located on the Akuapem Mountains. It lies, to the equator, between latitude 6.0154° and 6.0554° N and to the Greenwich Meridian, between longitude -0.0834° and 0.503° W. The area is elevated 448m above sea level with an averaging temperature of 23.88°C.

3.3 Target Population

The target population for the study was 2021 SHS 3 Science and Home Economics students in the district. The accessible population for the study, however, comprised Adukrom Senior High Technical School selected from the target population. This school was chosen based on the willingness of the school head and science teachers to participate in the study; and proximity of the school to the researcher.

3.4 Accessible Population

The accessible population was all the third-year science and home economics students of the school who offer Biology as one of their elective subject. The total number of the accessible population is 100, with 50 students per class.

3.5 Sample and Sampling Procedure

The sample for this study was made up of students in two intact SHS 3 classes in the selected school. The sample size used for the study was 100 students. Fifty (50) students were chosen from the Home Economics class with the other fifty (50) students from the science class. They were further grouped into experimental and control groups. Both classes included in the study were selected by purposive sampling. Third year SHS students were used in the study because “Photosynthesis” is taught during the third year of the SHS integrated science programme as contained in the SHS Biology syllabus. Participants in this study were all of similar educational background as they have been taught Photosynthesis at the junior high school level and they have basic knowledge of the concept. The participants were categorized into the experimental groups and the control group based on the performance of the intact classes on a pre-test instrument, "students" knowledge of Photosynthesis Test" – SKPT used in the study. The pre-test instrument was administered to all participants in the selected SHS in their respective classrooms at the same time in the school. Mean scores obtained by the intact classes on the SKPT were used as the basis of the categorization of participants into the experimental and control groups. The classes that obtained the lower mean scores were designated as the control groups. This was alone to investigate whether the performance of the classes with the lower mean scores would improve much more with the 5e instructional approach than that with the highest mean score, which were taught with the traditional instructional approach.

3.6 Research Respondents

One hundred (100) third year students of ASHS participated in the research work. This number comprises 50 students each from home economics class and science class, with each class forming and control and the experimental group. The control group was made up of 15 male and 35 female students whereas the experimental group was made up of 10 male and 40 female students. The age range of the respondents was 18 to 20 years. The distribution of the respondents according to their group and gender is outlined in Table 1.

Table 1: Distribution of respondents according to their group and gender

Gender Group	Male	Female	Total
Control	15	35	50
Experimental	10	40	50
Total	25	75	100

3.7 Research Instruments

The main instruments employed in this research work were tests, i.e., pre-test and post-test and open-ended focus group interview.

3.7.1 Tests (Pre-test and Post-test)

The data collecting instruments were paper and pencil test of comparable standard, developed by Laringtey (2014). This was adopted and modified by the researcher to collect quantitative data from all participants. The test instruments were named "Students Knowledge of Photosynthesis Test" – SKPT and "C" – SAPT'', which were adopted and modified from Laringtey (2014) ‟. The SKPT and SAPT were used as the pre-test and post-test instruments respectively. The SKPT was used to assess the participants‟ knowledge and difficulty with the concept of Photosynthesis‟ in order to have a baseline about all the participants before the implementation of the interventions. The SAPT was however, designed to measure participants‟ achievement after the implementation of the interventions. The SKPT and SAPT consisted of 18 and 19 test items respectively, which were made up of multiple choice questions, fill-in the blanks items and essay type questions. Preceding each set of test instruments was a portion that briefly asked participants to provide their personal data, such as identification number (ID), gender, class and school. This portion also contained general instructions to candidates in answering the items. The SKPT consists of 8 multiple choice questions, 6 fill-in the blanks items and 4 essay type questions whereas the SAPT comprises of 10 multiple choice questions, 4 fill-in the blanks items and 5 essay type questions. The SKPT and SAPT last for a duration of 1hr 15 mins and 1hr 30 mins respectively. The maximum score for SKPT is 50 marks whereas that of SAPT is 60 marks.

3.7.2 Interviews

Two sets of different open-ended interview questions were designed to be administered to two set of interviewees. One set was administered to the focus group selected from the control group while the other set was also administered to the focus group selected from the experimental group. The interview for the control group seeks to investigate the views and effects of students' misconceptions about photosynthesis. On the other hand, that of the experimental group aims to investigate the perceptions of learners about the employment of the 5E LCM in teaching and learning of photosynthesis.

3.8 Validity of the Instruments

Validity is the extent to which results obtained from the analysis of the data actually represent the problem under study. The instruments went through validation analysis by the supervisor of the study. This resulted in the modification of some items and the cancellation and the inclusion of new ones. Additionally, some experienced researchers in the Department of Science at Adukrom Senior High Technical School, did the face validity of the instruments. Both items in pre- and post-tests exercises were validated by comparing what they were measuring to the rationale and the goals of the SHS Biology syllabus Their inputs were used to correct errors that might influence the results. These exercises led to a review of some items and modifications of the instruments before using them for the study.

The interview questionnaires were presented to colleague researchers for their views and inputs. The structure of some of the questions were reframed in order to prevent ambiguity. Aside, one English language tutor assessed the questionnaires in terms of expression and sentencing. Based on his/her remarks, necessary changes were infected.

3.9 Reliability of the Instruments

According to Kombo and Tromp (2006), reliability refers to the consistency of the scores obtained, how consistent they are from one administration of an instrument to another. Reliability is the extent to which data can be trusted to represent genuine rather than spurious phenomena. Reliability is when results are consistent over a period of time and an accurate representation of the total population under study and if the results of a study can be reproduced under a similar methodology, then the instrument is considered to be reliable. The test items were pre-tested to establish the reliability and internal consistency of the instruments. Simple linear correlation coefficient was calculated to ascertain the reliability of the instrument. A value of 0.71 was obtained which indicates that the instrument is reliable.

3.10 Data Collection Procedure

The data collection procedure was divided into three phases: pre-treatment phase, treatment phase and post-treatment phase.

3.10.1 Pre-treatment phase

This phase of the study lasted for one week in the selected school. The pre-treatment phase involved the administration of the pre-test instrument – SKPT to the participants in their respective classrooms. All the scripts were marked, recorded and the scores were collated for further processing. Mean scores obtained by the participants on the SKPT were used to assign the intact classes into the experimental and control groups. The class that obtained the lower mean score (11.12) was designated as the control group and the one with the higher mean score (11.72), as the experimental group. This was done to find out if the performance of the class with lower mean score would be improved than the one with the higher mean score after the treatments.

3.10.2 Treatment phase

The following are the description of the treatments administered to the two groups:

3.10.2.1 The experimental group: the learning cycle approach

Students in the experimental group were instructed with 5E LCBI. The designed 5E lessons were examined by experts in science education. At the beginning of the instruction the teacher divided the classroom into groups to maximize student-student interaction and relationship.

3.10.2.1.2 Engagement

The instruction began with the "Engagement" part. As a first step, the teacher asked several questions to activate the prior knowledge of students and stimulate their thinking such as; "What is food of plants?", "What is food of animals?". The teacher requested students to discuss the questions with their friends and write the answers to their notebooks. During the discussion, the teacher didn't interfere with the students.

After discussion, the teacher asked the answer of the question to the students and each group gave an answer reflecting their thinking to the teacher. In this way, the teacher had opportunity to view students' previous ideas. The answers of this question showed that most of the students have misconceptions related to food of plants. Students stated that water, inorganic salts, carbon dioxide, fertilizers and sunlight are food of plants.

3.10.2.1.3 Exploration:

In the exploration part the students were given an experimental situation, in which a green plant weighing 500 g without any soil on its roots, was planted in a tub of soil. The experimenter only watered the plant but did nothing else. After the plant had grown 5 years, the experimenter removed the plant and weighed it again. The weight of the plant was 4 kg. It was asked to students that what happened to the weight of the soil in the tub after the plant grew in it 5 years and gained so much weight. Three situations related with the weight of the soil were given to students, the soil has lost a lot of weight, the soil's weight stayed about the same, and the soil gained a lot of weight. The students have discussed with their classmates and noted their answers to their notebooks. When the teacher asked the answers of the students, most of the students said that the soil has lost a lot of weight by thinking the soil as the source of plants' weight. Both in the engagement part and exploration part, the teacher had an opportunity to observe students' misconceptions.

3.10.2.1.4 Explanation

In the explanation part, the teacher introduced the concept of producer, food of plants, photosynthesis, the purpose of photosynthesis, what plants need for photosynthesis, what plants produce as a result of the photosynthesis. In the explanation part the teacher emphasized misconceptions of students and explained why they are wrong.

3.10.2.1.5 Elaboration

In the elaboration part, the students discussed how they can design experiments to test what plants need for photosynthesis and what they produce as a result of photosynthesis. Then, they conducted the experiments. Students also discussed whether there are other factors that affect the photosynthesis (enzymes, temperature etc.) in this phase.

3.10.2.1.6 Evaluation

Assessment occurred at all points along the instruction. During the lesson the teacher asked questions to students, observed them through discussions and hands-on activities and decided whether they gained the necessary concepts or not. In addition to this, several questions including open-ended, multiple-choice questions are asked to students at the end of the instruction. The teacher distributed the questions to the students and gave time to think about the answers of the questions. Then the answers of the questions are discussed in the classroom.

3.10.2.2 Control Group

Students in the control group received traditional instruction. At the beginning of the instruction, they read the topic from their textbooks in the classroom. Then, the teacher explained the concepts related with photosynthesis in plants; concept of producer, food of plants, photosynthesis, the purpose of photosynthesis, what plants need for photosynthesis, what plants produce as a result of the photosynthesis, how and when respiration occurs in plants, by using lecture and discussion methods. After explaining the concepts, the teacher conducted four experiments related with photosynthesis given in the textbook. The students did not actively participate in experiments, they only observed their teacher while she was conducting the experiments. The teacher demonstrated the experiments and she followed the procedure given in the textbook while conducting the experiments. After the experiments the teacher asked several questions related with the results of the experiments, took the student responses and explained the results.

3.10.3 Post-treatment phase

The posttest instrument, Student's Achievement in Photosynthesis Test –SAPT, was administered to all participants after experimental groups had been treated with the intervention and the control groups treated with the traditional instructional approach. This is done to assess the impact of 5e learning style in students' achievement in photosynthesis. The post-treatment phase of the study was done in the last week of data collection period in selected the school. After the implementation of the interventions in the school, the SAPT was administered to all participants in the experimental groups and the control group.

3.11 Data Analysis Procedure

The data collected from the pre-test assessments was analysed using Microsoft Excel by comparing the mean scores of the two cohorts to establish whether individuals in the two cohorts have similar background, knowledge and ability levels before applying the respective teaching approach on either group. The data gathered from the post-interventional test was also analysed using Microsoft Excel Version 2015. Since the group involved in the study were made up of two different groups, two sets of performances were compared using t-test. The aim of using t-test was to determine whether there was a significance difference between the achievement scores of the two cohorts. The results generated were tabulated for easy comprehension and drawing of conclusion.

3.12 Ethical Issues

Visit was made to the assistant headmaster, academic's office to ask for permission in order to conduct the research study. Also, the HoD of the Science Department, fellow Biology teachers as well as other science teachers of the department were informed about my intention to carry out a research. The essence of the study as well as the strategic measures to be employed were discussed to the personality mentioned above. Besides, respondents' confidentiality in terms of identity and marks obtained were kept secret.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

Chapter four of this research study, outlines the results and its discussion in terms of the objectives and the hypotheses stated in chapter one. The discussion was centered on quantitative and qualitative results.

4.1 Bio-data Analysis of the Respondents

The bio-data information of the respondents was outlined in Table 2. In all, seventy five girls and twenty five boys were selected for the research study. They were all third year students who offered Biology as one of their four elective subjects.

Table 2: Bio-data of the Respondents

Gender	75 females and 25 males
Age range	18 to 20 years
Level of education	3rd years of second cycle
Religion	All Christians
Nationality	All Ghanaians

4.2 Quantitative Results

4.2.1 Research Question 1

To what extent is the control group's pre-test score significantly different from that of the experimental group before the intervention?

As a way of answering this research question, respondents' pre-test scores were subjected to student's t-test analysis in order to compare the mean values and standard deviations of the two groups. Also, the p-value obtained is compared to 0.05 alpha level of significance to ascertain any significant difference between the control and the experimental group.

4.2.2 Null Hypothesis 1

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

4.2.3 Discussion Relating to Research Question 1

The results outlined in Table 3 indicates that the difference in the performance of the control group (11.12) and experimental group (11.72) in the pre-test yielded a t-statistics of 0.54 and a p-value of 0.59. This result shows no statistically significant difference since the p-value obtained (0.59) was greater than 0.05 alpha level of significance. Though the average score (11.72) of the experimental group is slightly higher than that of the control group (11.12) students' pre-test scores [$t_{(98)}$=0.54, p>0.05), that does not produce any significant difference. This result indicates that the control and experimental groups' SKPT are similar. This revelation supports the argument of Creswell (2012), that pre-test is relevant in experimental research in order to ensure that the groups are at par so as to attribute any significant difference realised latter as the true effect of the treatment carried out.

In order to confirm this argument of Creswell, the researcher intentionally assigned the class that obtained the lower mean score (11.12) as the control group and the one with the higher mean score (11.72) as the experimental group. This was done to find out if the performance of the class with lower mean scores would be improved than those with the higher mean score after the treatments.

Table 3: Unpaired samples t-test results of the pre-test scores for control and experimental groups

Group	N	$\bar{X}$	SD	df	t stat	p-value
Control	50	11.12	5.15	98	0.54	0.59
Experimental	50	11.72	5.93			

***Significant at p<0.05**

4.2.4 Research Question 2

To what extent is the experimental group's post-test score significantly different from that of the control group after introducing the experimental group to 5E learning models?

4.2.5 Null Hypothesis 2

There is no significant difference in achievement in the cognitive levels between students taught with 5E learning cycle approach and those taught with traditional method.

Again, in response to this research question, participants' post-test scores were subjected to student's t-test analysis in order to compare the mean values and standard deviations of the two groups. Also, the p-value obtained is compared to 0.05 alpha level of significance to ascertain any significant difference between the control and the experimental group.

4.2.6 Discussion Relating to Research Question 2

From Table 4, it is clear that the mean score of the experimental group students ($\bar{X}$=32.23, SD=11.38) was higher as compare to that of the control group ($\bar{X}$=23.96, SD=9.68). A significant difference was found between the performance of the experimental group participants and control group participants in the SAPT scores [$t_{(98)}$ = -3.96, $p<0.05$] in that the p-value obtained (0.0001) was far less than 0.05 alpha level of significance.

In consideration to the control and experimental groups' mean marks on the pre-test (SKPT) and the post-test (SAPT) shown in Table 3 and Table 4 respectively, it is clear that there is a difference between the means of the SKPT and SAPT. The mean marks of each group increased after the treatment; however, the experimental group which was taught using 5E learning style saw a higher increment than the control group which was also taught by the TI. Hence the significant difference occurred in favour of the experimental group. This result supports other results of similar researches conducted by different researchers at different places. For example, studies showed that 5E Learning Cycle approach had a positive effect on students understanding (Colburn & Clough, 1997; Bevenino, Dengel & Adams, 1999; Lord, 1999), scientific reasoning (Boddy, Watson & Aubusson, 2003) and positive attitudes toward science (Boddy & Aubusson, 2003; Akar, 2005). Again, Lord (1999) conducted a study that compared two classes taught by traditional method with two classes also taught with 5E LCM. The 5E LCM used involved small heterogeneous groups, who worked on thought provoking scenarios and critical thinking questions or constructed concept maps. The results indicated that the experimental groups had much greater understanding of the information covered especially on questions that required interpretation. Also, a significant difference was found in the feedback from the students. Most of the experimental group students wrote positive comments about the course. A study performed by Campbell (2000), investigated the fifth-grade students' understanding of force and motion concepts through the use of the 5E learning cycle. Students participated in investigations about force and motion concepts weekly for a period of 14 weeks. Findings showed that students' knowledge about force and motion concepts increased although their knowledge as demonstrated on paper was insufficient. It seemed that the students were of the same opinion that learning science through text book was not the best way for them.

Linking the SAPT result of this research work to those discussed above, there no denying the fact that the performance of the experimental group over the control group can be attributed to as the effect of the intervention, i.e., the 5E LCM. On the basis of the foregoing research results and analysis, the research wants to recommend the methodology not only to all Biology teachers of SHSs but also all other science subjects – Chemistry, Physics and Elective Mathematics – teachers.

Table 4: Unpaired samples t-test results of the post-test scores for control and experimental groups

Group	**N**	$\bar{X}$	**SD**	**df**	**t stat**	**p-value**
Control	50	23.96	9.68	98	-3.96	0.0001
Experimental	50	32.32	11.38			

***Significant at p<0.05**

4.3 Qualitative Results

This has to do with the discussions of interview and observation results as provided by the respondents and researcher's own observation respectively.

4.3.1 Research Question 3

What are the perceptions of students about the use of 5E LCM approach in teaching and learning photosynthesis in plants in ASHTS?

In response to this question, students' views about photosynthesis in plant were taken and presented as follows:

4.3.2 Discussion Relating to Research Question 3

Table 5 outlines the various views expressed by the respondents (control group) about the topic photosynthesis. Forty five out of fifty students of the control group representing 90% saw the topic as one that contains a lot of technical terms. They mentioned some of these terminologies to include *"oxaloacetate", "nicotinamide", "phosphoglyceraldehyde", "photolysis", "pyruvate", "thylakoid"* etc. Forty-one of the respondents representing 82% contended that these terminologies made the topic very complex and therefore not easy to understand while 39 giving a percentage of 78 the topic contains a lot of chemical equations. "Balancing of chemical equations is very challenging so we do not like the topic". Some of the respondents (f=26), representing 52% are also of the view that "we do not need to study that topic to pass our WASSCE exam in Biology". On the least side 22% and 18% of the respondents are of the view that the topic should be completely deleted from the syllabus or the teachers should not teach the topic respectively. These views expressed by the respondents align with research findings conducted by other researchers in the past. For example, according to Lazarowitz and Penso (1992) overloaded biology curricula, the abstract and interdisciplinary nature of biological concepts and difficulties with the textbooks are the factors preventing students from learning. This overloaded curricular may lead the students to memorize. This of course prevents meaningful learning. Fraser (1998) indicates that there is a close relationship between students' perception of their classroom learning environment and their success. Osborne and Collins (2001) reported that students diminishing interest in learning biology was due to the curriculum content being overloaded and not generally related to working life. The lack of discussion of topics of interest, the absence of creative expression opportunities, alienation of science from society and the prevalence of isolated science subject. Teacher's style of biology teaching and teaching methods and techniques may also affect students learning in biology (Cimer, 2004). They maintain that if students are not happy about the way biology is taught, they may show disinterest in the negative attitude towards biology and its teaching.

In addition to determining the factors that negatively affects the students learning in biology, understanding students view on what makes their biology learning effective is crucial as many researchers suggest that in order to improve the quality of biology and learning in school, student views must be taken into consideration by researchers, teacher educators, schools and teachers (Fullan, 1991; Macbeath & Mortimore, 2001; Cimer, 2004; Ekici, 2010). The authors argued that what students say about teaching and learning and schooling is not only worth listening to but provides an important foundation for thinking about ways of improving teaching and learning. More so, it is thought that how students perceive the learning environment affects their attitudes toward biology and its learning (Atilla, 2011). Therefore, understanding secondary school students' perception of biology will help policy makers, teachers and teacher educators to plan more effective teaching activities that can help students learn biology better and have more positive attitudes towards it

Table 5: Students views about the topic photosynthesis

S/N	Students' View	Frequency	Percentage
1.	The topic contains a lot of terminologies	45	90%
2.	The topic is very complex to our understanding	41	82%
3.	the topic contains a lot of chemical equations even though it is not a chemistry topic	39	78%
4.	We completely dislike the topic	36	72%
5.	It is a boring topic because it is very difficult to understand	33	66%
6.	We tend to rote memorization of the terminologies	28	56%
7.	We do not need to study that topic to pass our WASSCE examination in Biology	26	52%
8.	Abstract learning occurred	18	36%
9.	The topic is bulky	15	30%
10.	The topic should be deleted from the syllabus	11	22%
11.	The teachers should not teach that particular topic	9	18%

Again, Table 6 indicates that 21 out of 24 interviewees representing 87.5% selected from the experimental group see the 5E LCM methodology as one that aided them to discover new ideas in the course of teaching and learning the topic photosynthesis. Also, 19 interviewees representing 79.2% stated that the methodology facilitated the way the construct new information. These revelations by the respondents agrees with other results of past researches. For example, Karplus (1977) maintains that the utilisation of LCM is a strategy of teaching which purports to be consistent with the ways and means people spontaneously discover and construct knowledge. In other words, anyone who has reflected upon how to teach effectively has no doubt discovered aspects of the learning cycle (Lawson et.al., 1989).

Furthermore, 18 out of 24 interviewees representing 75.0% expressed the view that 5E LCM enable them to review their previous lesson in a manner that they do not encounter any difficulties. Also, 16 and 15 participants respectively representing 66.7% and 62.5% mentioned that the 5E instructional technique helped them gain new learning experiences and therefore are motivated to be class regularly respectively. This outcome expressed by the students support a similar revelation put forward by Duran and Duran (2004) that “I have used the 5E Model and notice that the students are more motivated to learn the topic after I engage them in the beginning. The extend phase allows them to relate science to other subject areas so they see the purpose of what’s being taught”. This tells us that the methodology is effective in motivating learners as they are always punctual in class. Punctuality is class is a function to the academic performance of learners. No wonder there was a statistically significance difference in the performance of the learners in the SAPT (post-test) in favour of the experimental group participants. This higher performance was expressed by 12 students representing 50% of the interviewees that the methodology their performance in that they were able to scored higher marks. As stated in the literature review to support this findings, Ozsevgec (2006) researched into the impact of 5E LCM on 5th grade participants’ achievement and attitudes toward science and technology programmes. It was revealed that a statistically significant mean difference was found in favour of 5E learning cycle group.

Rather on a low side, 6 participants representing a percentage point of 25 mentioned that "our understanding of new concepts taught by 5E LCM was greatly enhanced". This supports Ausubel 1963's finding that 5E learning cycle facilitated a meaningful learning by providing application tasks that help respondents link their understanding of the concept to other experiences in science and in daily life activities.

To support all these findings, a study on the effectiveness of 5E LCM on 8th grade participants' achievement on photosynthesis and respiration in plants was carried by Cakiroglu (2006). Participants' knowledge on topic was determined by a test instrument designed by Haslam and Treagust. The designed instrument was applied to 67 eight-grade participants in two separate classes of the same elementary school as pre-test and post-test. The experimental group participants (n=33) studied the lessons by 5E learning cycle instruction whereas the control group participants (n=34) studied the lessons by TI. A statistically significant difference was achieved between the experimental and the control group participants in favour of 5E LCM.

Table 6: Students' views about their engagement with 5E LCM

Students' Perceptions	Frequency	Percentage
The 5E LCM helped us discover new ideas	21	87.7%
The 5E LCM facilitated the way we constructed new information	19	79.2%
We were able to review our previous lessons	18	75.0%
We gained new learning experiences	16	66.7%
The methodology motivated us to be in class	15	62.5%
The 5E LCM promoted effective communication in class	15	62.5%
The 5E LCM helped us discuss our findings with other groups	15	62.5%
We were able to relate well among ourselves	13	54.2%
The 5E LCM helped us score higher marks	12	50.0%
We were able to analyse and interpret our results	10	41.7%
Application of our understanding in solving new concepts	10	41.7%
Our misconceptions were erased	8	33.3%
Our understanding of new concepts taught by 5E LCM was greatly enhanced	6	25.0%
We were able to explain concepts in our own ways correctly	4	16.7%

4.4.1 Research Question 4

What are the effects of SHS Students misconceptions about photosynthesis in plants in Adukrom Senior High Technical School (ASHS)?

Judging from the views expressed by the respondents as outlined in Table 5 and linking it to the effects of students' misconceptions held about the topic 'photosynthesis', it is clear that the effects had imparted negatively on how students learn and behave in class as shown in Figure 2. Sixteen (16) respondents representing 32% of the control group stated that they were inactive in class during a lesson on photosynthesis. This is because they see the topic to be more complex to their understanding. Also 9 students representing 18% normally come to class but late. This means that they always missed the introductory part of the lesson which serves as the basis for lesson development. There is no way one could understand a lesson perfectly when the foundation is weak from the beginning. Furthermore, 16% of the respondents stated that they do absent themselves from class whenever it is time for a lesson on photosynthesis. This may possibly be the group of respondents who felt that "*we do not need to study that topic to pass our WASSCE exam in Biology",* and therefore see no reason(s) why they should take part in the lesson. In addition to these, 5 and 12 students of the control group representing 10% and 24% found themselves sleeping in class and doing other things respectively. These research findings support the outcomes of other researches conducted in the past. For example, According to Tekkaya, Özkan and Sungur (2001), many concepts and topics in biology including protein synthesis, respiration and photosynthesis can be perceived as difficult to learn by secondary school students. Tekkaya, Özkan and Sungur (2001) also found that hormones, genes and chromosomes, mitosis and meiosis, the nervous system were also considered difficult concepts by secondary school students. Experiencing difficulties in so many topics in biology negatively affect students' motivation and achievement (Ozcan, 2003). There are many reasons why students have difficulties in learning biological concepts (Lazarowitz & Penso, 1992; Cimer, 2004; Zeidan, 2010). The nature of the subject itself and its teaching methods are among other factors; the reasons for the difficulties in learning, according to Lazarowitz and Penso (1992), the biological level of organization and abstract nature of concepts make biology learning difficult. Furthermore, students learning and study habits as well as teachers' lack of mastery in Biology and teaching were some of the reasons they had difficulties in learning the subject. Therefore, teachers' competence and knowledge in both biology as a discipline and its teaching are crucial for enhancing students learning.

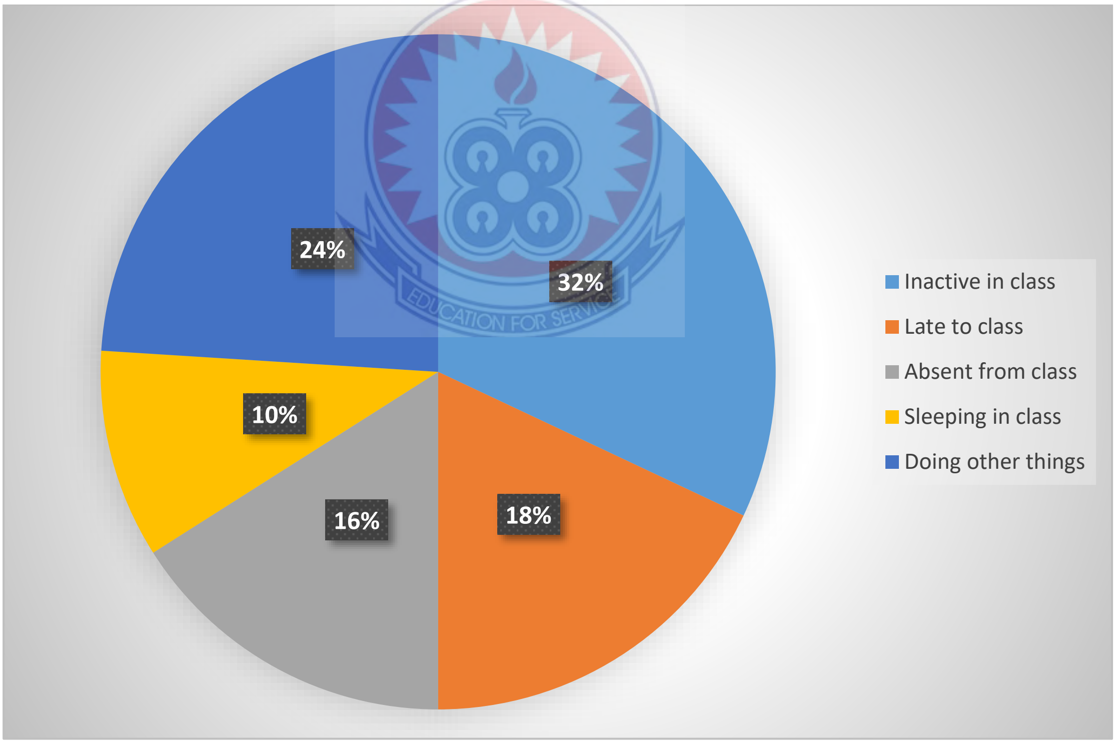

Figure 2: Effects of students' misconceptions on photosynthesis

CHAPTER FIVE

SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

5.0 Overview

Chapter five provides a summary of the processes and findings employed in the research work. Conclusions were drawn concerning the research questions and hypotheses as outlined in chapter two of this thesis. Lastly, recommendations and suggestions were put forward to provide a guideline to any one or an organization interest in conducting similar research.

5.1 Summary

The purpose for conducting this research work was to investigate the impact of 5E learning styles on participants' achievement in photosynthesis in Adukrom Senior High Technical School, ASHTS. The study was centered on four objectives, giving rise to four research questions and two research hypotheses. In order to achieve the objectives and provide answers to the research questions, the researcher carried out a quasi-experimental research in the school mentioned above. In the process to data collection, 100 third year Science and Home Economics students were selected as respondents using purposive sampling technique. The respondents were grouped into two groups of experimental and control. Data was collected using SKPT and SAPT as well as focus group interview.

The researcher first conducted a SKPT. This was followed by a six-week of rigorous classroom intervention using the 5E LCM. This was immediately followed by a SAPT (post-test). The research period lasted five months and was characterized by a lot of classroom activities.

5.2 Conclusions

This study examined the impact of 5E LCM on participants' achievement in photosynthesis of third year Science and Home Economics students of ASHTS. Research instruments used were tests, i.e., SAPT and SKPT for pre-test and post-test respectively and interview. During the intervention period, the control group was taught using TI whereas the experimental group was instructed using the 5E LCM strategy.

The study also indicated that the employment of the 5E LCM was an excellent instructional strategy in enhancing the way the students discover new ideas of learning. It also facilitated effective communication skills among the participants who were taught using the technique.

Participants of the experimental group expressed their view about the use of 5E LCM as a methodology in teaching and learning the topic under consideration. Their views and comments proved that the methodology promoted their attendance in class and therefore were able to score higher marks in the SAPT. Some of their views and comments concerning the utilization of the 5E strategy include, but not limited to the following:

a. Our misconceptions about the topic were completely erased
b. We gain new learning experiences
c. We were able to review our previous lessons
d. Our comprehension of new concepts was greatly enhanced

Regarding these views outlined by the respondents, it is clear that the 5E methodology was effective classroom tool for facilitating teaching and learning of photosynthesis. The 5E LCM serves as a unique learning style that aids science educators create science instructions that illustrate constructivist, reform-based, best teaching approaches.

5.3 Recommendations

In light of the outcomes produced from this study, the researcher suggests and put forward the following recommendations that:

a. Science teachers in Adukrom Senior High Technical School should incorporate the 5E LCM into the teaching and learning of Biology and other science subjects in the second.
b. The District Education Directorate of Okere should, as a matter of urgency, organize Continuous Professional Development, CPD workshops for in-service teachers of ASHTS to upgrade their knowledge in designing and using the 5E LCM in science instruction
c. Universities and Colleges mandated to train teachers are urged to incorporate structures of designing 5E LCM in the initial teacher training courses.
d. Similar studies should be carried out on the use of 5E LCM in different districts with different respondents as well as different subject areas.

5.4 Suggestions for Further Research

To have more insight into the impact of 5E learning styles on students' achievement, the author suggests the following, that:

1. the research study may be replicated in other Metropolitan, Municipal and Districts throughout the country.
2. the duration for the intervention be extended to cover a semester or a whole academic year, paving the way for the use of more than two Biology topics in the future study.
3. three different groups at the same academic level be used in the future research study. The first, second and third group be taught using the 5E learning style, concept mapping and traditional method of teaching respectively to ascertain if the 5E Learning Style can still produce the same result as this study or prove otherwise.

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APPENDICES

Appendix A: List of Abbreviations

ADP	Adenosine Diphosphate
ASHTS	Adukrom Senior High Technical School
ATP	Adenosine Triphosphate
BSCS	Biological Sciences Curriculum Study
CD	Compact Disk
CPD	Continuous Professional Development
CO_2	Carbon (IV) oxide
DNA	Deoxyribonucleic Acid
GES	Ghana Education Service
H^+	Hydrogen ion
HoD	Head of Department
LCBI	Learning Cycle Based Instruction
LCIM	Learning Cycle Instructional Model
LCM	Learning Cycle Model
NADP	Nicotinamide Adenine Dinucleotide Phosphate
NADPH	Reduced Nicotinamide Adenine Dinucleotide Phosphate
O_2	Molecular Oxygen
PCK	Pedagogical Content Knowledge
SAPT	Students Achievement Photosynthesis Test
SHS	Senior High School
SKPT	Students Knowledge of Photosynthesis Test
TI	Traditional Instruction

Appendix B: Sample of Pre-test Questions

Knowledge of Photosynthesis Test (SKPT)

Student's ID………………………………………………………………………

Gender of Participant…………………. **Class of Participant**…………………….

School of Participant…………………………………………………………………

Time allowed: 1 Hr 15 Mins

GENERAL INSTRUCTIONS: Answer all the questions on the question paper by completing the gaps or circling the correct letter multiple choice or true/false questions

1. The energy needed for photosynthesis to occur is obtained from
   a. Water
   b. Sunlight
   c. Chlorophyll
   d. Soil
2. Photosynthesis occurs in green plants because they contain….
   a. Water
   b. Energy
   c. Chlorophyll
   d. Stem

3. What is the fate of glucose produced during the process of photosynthesis?

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4. Explain the term photolysis

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5. The raw materials for photosynthesis include water and ……………………..
   a. O_2
   b. H_2
   c. CO_2
   d. NO_3
6. Photosynthesis takes place in which part of the plant?
   a. Leaves
   b. Roots
   c. Stem
   d. Branches
7. Glucose is a by-product of photosynthesis
   a. True
   b. False
8. Write a balanced chemical equation for photosynthesis

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9. What observation is made when testing for starch in a leaf?

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10. Photosynthesis helps in reducing the amount of oxygen in the atmosphere

a. True

b. False

11. What is photosynthesis?

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12. State two importance of photosynthesis

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13. The photosynthetic cells of a plant are located in the

    a. Branches

    b. Stems

    c. Roots

    d. Leaves

14. Which of these is the hydrogen acceptor in photosynthesis?

    a. FAD

    b. NAD

    c. ADP

    d. NADP

15. List the two products of the light dependent stage of photosynthesis

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16. List any four photosynthetic organisms

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17. Name the appropriate reagent used when testing for starch in a leaf

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18. State four factors that affect the rate of photosynthesis in plants

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Appendix C: Sample of Post-test Questions

Students' Achievement of Photosynthesis Test (SAPT)

STUDENT ID...

Gender of Participant: ....Class of Participant ....

School of Participant: ....

Time allowed: 1 Hr 30 Mins

GENERAL INSTRUCTIONS: Answer all questions on the question paper by filling the gaps or by circling the correct letter where these are multiple choice or true/false questions

1. Glucose is a by-product of photosynthesis
   a. True
   b. False
2. Chlorophyll is found in the chloroplast
   a. True
   b. False
3. The energy needed for photosynthesis to occur is obtained from
   a. Water
   b. Sunlight
   c. Chlorophyll
   d. Soil
4. Sugar solution is used to test for starch
   a. True
   b. False

5. Explain the term photosynthesis

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6. Carbon dioxide and water are the main materials for photosynthesis

   a. True

   b. False

7. Identify two importance of photosynthesis

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8. Photosynthesis help reduce the amount of oxygen in the air

   a. True

   b. False

9. Which gas is needed for photosynthesis to occur?

   a. CO_2

   b. N_2

c. O_2

d. H_2

10. The dark stage of photosynthesis takes place in the

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11. Name the enzyme that affects the dark stage of photosynthesis

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12. Water for photosynthesis is from the………………………

a. Atmosphere

b. Sun

c. Rocks

d. Soil

13. Photosynthesis takes place in which part of the plant?

a. Stem

b. Roots

c. Leaves

d. Branches

14. Explain how pollution affects photosynthesis

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15. Photosynthesis occurs in green plants because they contain…........................

    a. Water
    b. Energy
    c. Chlorophyll
    d. Stem

16. Write the balanced chemical equation for photosynthesis

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17. Describe a simple experiment perform by you or your teacher in the laboratory to show that chlorophyll is necessary for photosynthesis.

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18. Write the full meaning of each of the following abbreviations

   a. NADP……………………………………………………………………

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      ………………………………………………………………………………

   b. ATP………………………………………………………………………

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   c. RUBP……………………………………………………………………

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19. Briefly describe the dark stage of photosynthesis

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Appendix D: Marking Scheme for the SKPT (Pre-test)

1. B **2 marks**
2. C **2 marks**
3. **Fate of glucose produced during photosynthesis**
    a. The glucose produced is quickly converted to starch in the leaf but is later broken down to sugar and transported to other parts of the plant.
    b. The excess glucose is stored permanently in the form of starch and sucrose in plant organs.
    c. Glucose formed may be converted to other complex plant products such as lipids and stored
    d. Glucose produced is used in internal respiration to produce energy for the plant

Any 3×2 = 6 marks

4. **Explanation of photolysis**

Photolysis is the photochemical splitting of water (1) into hydrogen ions (H^+) and hydroxyl ions (OH^-) (1). The hydroxyl component is converted into water (1) and oxygen as a by-product (1). **4 marks**

5. C **2 marks**
6. A **2 marks**
7. B **2 marks**
8. $6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$ **R=1, P=1, B=1** = **3 marks**
9. A blue-black colour is formed (2) indicating the presence of starch in the leaf (1) **3 marks**

10. B **2 marks**

11. <u>Meaning of photosynthesis</u>

a. Photosynthesis is defined as a chemical process whereby autotrophic organisms such as plants
b. synthesize simple sugar from carbon (IV) oxide and water
c. in the presence of sunlight and chlorophyll
d. with oxygen being given off as a by-product. **4×1= 4 marks**

12. <u>Two importance of photosynthesis</u>

a. It provides food for all living organisms
b. Replenish the atmosphere with oxygen
c. Reduces CO_2 concentration in the atmosphere
d. Reduces greenhouse effects and hence global warming

Any 2×2 = 4 marks

13. D **2 marks**

14. D **2 marks**

15. ATP and $NADPH_2$ **2 marks**

16. Four autotrophic organisms

a. Green plants
b. Green alga
c. Some species of bacteria
d. Spirogyra **4×½ = 2 marks**

17. Iodine solution **2 marks**

18. <u>Four factors that affect the rate of photosynthesis</u>

a. Carbon (IV) oxide concentration

b. Temperature

c. Light intensity

d. Chlorophyll concentration

e. Pollutants

f. Level of water in the growth medium **Any 4×1 = 4 marks**

Highest score for the SKPT is 50 marks

Appendix E: Sample of SAPT (post-test) Marking Scheme

1. B **2 marks**
2. A **2 marks**
3. B **2 marks**
4. B **2 marks**
5. **<u>Explanation of photosynthesis</u>**
   a. Photosynthesis is defined as a chemical process whereby autotrophic organisms such as plants
   b. synthesize simple sugar from carbon (IV) oxide and water
   c. in the presence of sunlight and chlorophyll
   d. with oxygen being given off as a by-product.
   e. Photosynthesis occurs in living things at the site of chloroplast
   f. Organisms that carry out photosynthesis are called autotrophs
   g. Examples include green plants, green alga, spirogyra tec

   Any 6×1 = 6 marks
6. A **2 marks**
7. **<u>Two importance of photosynthesis</u>**
   a. It provides food for all living organisms
   b. Replenish the atmosphere with oxygen
   c. Reduces CO_2 concentration in the atmosphere
   d. Reduces greenhouse effects and hence global warming

   Any 2×2 = 4 marks
8. B **2 marks**
9. A **2 marks**

10. Stroma of the chloroplast **2 marks**

11. Ribulose Bisphosphate Carboxylase Oxygenase **2 marks**

12. D **2 marks**

13. C **2 marks**

14. **How pollution affects photosynthesis**

    a. Atmospheric pollution in cities may cause smog and reduce the amount of light reaching the plant

    b. Specific pollutants may interfere with chlorophyll production and the mechanism of photosynthesis itself

    c. Pollutants in the water and soil may stress the plant and inhibit its growth

    d. Reducing the area of the plant exposed to sunlight

    e. Common pollutant like CO_2 however, increases the rate of photosynthesis

    Any 2×2 = 4 marks

15. C **2 marks**

16. $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ **R=1, P=1, B=1 = 3 marks**

17. **Simple experiment to investigate the need for chlorophyll for photosynthesis**

    a. **Apparatus:** variegated leaf, iodine solution, ethanol, beaker, water, Bunsun Burner, wire gauze, tripod stand etc **Any 4×½ = 2 marks**

    b. Procedure:

    - Take a variegated leaf which has been exposed to sunlight
    - Make a sketch of the pattern of green and white patches of the leaf

- Carry out a starch test on the complete leaf
- Compare the pattern of green patches for starch in the leaf with the original sketch **Any 2 ×1 = 2 marks**

c. **Observation:**

- Starch is only produced as a result of photosynthesis in the green areas of the leaf. **2 marks**

d. **Conclusion:**

- Chlorophyll is necessary for photosynthesis to occur.

2 marks

18.

a. NADP….Nicotinamide Adenine Dinucleotide Phosphate

b. ATP……Adenosine Triphosphate

c. RUBP….Ribulose Bisphosphate

Correct spelling to score 3 ×2 = 6 marks

19. Description of the dark stage of photosynthesis

- The dark stage takes place in the stroma and is controlled by enzyme (RUBISCO) and therefore affected by temperature.
- Atmospheric CO_2 enters the chloroplast and is accepted by RUBP, a 5C sugar.
- To form unstable 6C compound
- The unstable 6C compound breaks immediately into two molecules of 3C compound
- Called glycerate-3-phosphate (GP) as the first product of photosynthesis

- The GP is reduced to a 3C sugar called phosphoglyceraldehyde (PGAL)
- Using hydrogen provided by $NADPH_2$ produced in the light stage
- The PGAL is converted into 6C sugar which can be further converted into starch for storage.
- The dark stage functions if ATP, $NADPH_2$and CO_2 are present
- The cycle is called the Calvin cycle

Any 5×1 = 5 marks

Highest score for the SAPT is 60 marks