UNIVERSITY OF CAPE COAST

EFFECTS OF CONCEPT CARTOONS AND CONCEPTUAL CHANGE TEXTS ON SENIOR HIGH SCHOOL STUDENTS' UNDERSTANDING OF PHOTOSYNTHESIS

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BY

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Thesis submitted to the Department of Science Education of the Faculty of Science and Technology Education, College of Education Studies, University of Cape Coast, in partial fulfillment of the requirements for the award of Master of Philosophy degree in Science Education

SEPTEMBER 2024

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature: .... Date: ....

Name: Padmore Asamoah Gyamenah

Supervisor's Declaration

I hereby declare that the preparation and presentation of this thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Supervisor's Signature:................................... Date:.......................

Name: Dr. Deodat Charles Otami

ABSTRACT

This study aimed at exploring the effects of concept cartoons and conceptual change texts instructional approaches on Senior High School Students' understanding of concepts related to photosynthesis. Using the embedded mixed methods research design, a multi-stage sampling technique was employed to select 113 Form 3 students from three schools in the Jomoro and Ellembele educational districts to participate in the study. One-way analysis of variance (ANOVA), Paired sample t-test, independent sample t-test, Analysis of covariance (ANCOVA) and descriptive statistics were used to analyse data gained on students' achievements in concepts related to photosynthesis with Photosynthesis Achievement Test and a semi-structured interview as instruments. The results showed that prior to implementing the interventions, the students' in the groups were at par. There were significant gains in knowledge after the interventions for both control and experimental groups. Furthermore, the gap between low and high achievers could not be bridged for those taught with concept cartoons and conceptual change texts. Students' initial misconceptions about the concepts related to photosynthesis were changed. The study further revealed that students had positive views about the utility of concept cartoons and conceptual change texts in teaching and learning photosynthesis at the Senior High School level. Based on the findings of the study, it was recommended that concept cartoons and conceptual change texts teaching approaches should be employed in teaching difficult Biology concepts in the Senior High Schools Biology Curriculum.

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Finally, I owe it all to the highest God for His mercy, strength and protection all through the period of this study.

DEDICATION

To my belated father, Mr. Philip Asamoah Gyamenah.

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CHAPTER ONE

INTRODUCTION

Photosynthesis, a keys concept in senior high school biology, is established to be difficult for students to understand. Though knowledge of photosynthesis is considered key to understand survival of life on earth, students' poor understanding of the concept has attracted attention of many biology educators. Misconceptions of students and ineffective instructional approaches used to teach it is largely to be blamed. Therefore, this study sought to explore the effectiveness of conceptual change texts and concept cartoons instructional strategies in improving students' understanding of concepts related to Photosynthesis.

Background to the Study

Photosynthesis is considered to be an essential biochemical process on earth (Kurt, Gulay, Akta & Aksu, 2013; Marmaroti & Galanopoulou, 2006; Russel, Netherwood & Robinson, 2004). This is because the survival of most living organisms directly or indirectly depends on it (Esra & Ponar, 2010; Dimec, 2017). Thus, it is vital that learners at all levels of education have sufficient knowledge and understanding of concepts related to photosynthesis since it provides insights into how the ecosystems in the world is sustained and how it functions as a bridge between the living and non-living worlds (Dimec, 2017; Ozay & Oztaz, 2003).

Considering the importance of photosynthesis, it is normally referred to as the backbone of life on earth and students at all levels of education globally (i.e. Elementary, Secondary (SHS) as well as the Tertiary) are taught this concept. However, students at the various levels of education show inadequate understanding of concepts related to Photosynthesis (Esra & Ponar, 2010; Koba and Tweed, 2009; Lewis, 2009; Marmaroti & Galanopoulou, 2006; Russel et al., 2004) more especially at the senior high secondary level, where the process and mechanisms of photosynthesis are first taught (Sarpah, 2021). Students' misconceptions regarding concepts relating to photosynthesis is a serious contributing factor responsible for students' difficulty in understanding the concept (Dimec, 2017; Nas, 2010).

In Ghana, reports by the West African Examinations Council's Chief Examiners on Elective Biology for Senior High School (SHS) have consistently highlighted students' difficulty in answering questions on concepts related to photosynthesis (WAEC, 2015; 2016; 2017; 2018). The report seems to suggest that High School Students in Ghana lack understanding of concepts related to photosynthesis. For instance, in 2015, the report indicated that students lack understanding of how the leaf of a flowering plant is adapted to its function. In 2017, it noted that students show difficulty in outlining the procedure for testing starch in a leaf. The report in 2018 was not different when it indicated that students show inadequate knowledge of the process of photosynthesis. This buttresses Esra and Ponar (2010) who reported students' poor understanding of complex organic food substances manufactured when plants take in inorganic substances from the environment. Marmaroti and Galanopoulou (2006) earlier reported that students show inadequate understanding of the process of how energy is transformed and also show inadequate understanding of the function of chlorophyll with regards to photosynthesis and, thus, cannot perceive the process as a chemical reaction.

Tekkaya and Balci (2003) had reported senior secondary school students' misconceptions regarding concepts related to photosynthesis despite the fact that they are being exposed to it at the primary school level of education. This makes it difficult for students to understand (Kurt et al., 2013; Tlala, Kabirige & Osodo, 2014; Svandova, 2013; Nas, 2010). Marmaroti and Galanopoulou (2006), noted that students indicated plants receive their food directly from their environment, thus, confusing the process of photosynthesis with respiration. Similarly, Mintzes and Wandersee (2005) reported that students explained that plants eat by using their roots and, thus impede their understanding of the process of photosynthesis.

The Elective Biology syllabus for Ghanaians SHS recommends that teachers use the Activity-based instructional approaches to teach concepts. However, no specific one was indicated with respect to how to teach concepts related to photosynthesis. This has resulted in most biology teachers using ineffective instructional approaches such as the lecture approach to teach concepts related to photosynthesis which hinder students' understanding of the concept (Nkechinyere & Arokoyu, 2018). Okoli and Azubuike (2012) have earlier noted that scientific concepts including photosynthesis cannot be effectively learned if the instruction does not go beyond didacticism. Miles (2015), therefore, pointed out that biology teachers should employ instructional strategies that could improve understanding and thereby bringing academic success to every science student. This seem to resonate with Adu-Gyamfi

(2014)'s assertion when he noted that, teachers have the responsibility to identify the various alternative misconceptions students' bring to the classroom and discover innovative ways of instructing them to bring about a Conceptual change.

Studies underpinning the usefulness of instructional strategies that facilitate conceptual change is well documented (Armagan, Melike & Akin, 2017; Troyer, 2011; Abdul & Akhilesh, 2010). Conceptual change instructional strategy is an innovative teaching strategy where students' pre-existing conceptions are actively replaced by the correct scientifically acceptable concept (Armagan et al., 2017). As noted by Treagust, Duit and Widodo (2008), conceptual change pedagogical approach is not only effective in identifying students' misconceptions regarding biology concepts, but also, in recognizing the resistance to change these conceptions may have on further learning. This instructional strategy which depends on Piaget's notions of assimilation, accommodation, and disequilibrium (Ozmen, 2007) forms an alternative framework which identifies and corrects students' misconceptions (Troyer, 2011).

Although there are several conceptual change instructional strategies in science education, nevertheless, studies have shown that conceptual change texts (Alkhawaldeh & Salem, 2019; Abdul & Akhilesh, 2010; Cepni & Emine, 2010) and Concept cartoons (Akamca, Ellez & Hamurcu, 2009; Gafoor & Shilna, 2013) are very effective in enhancing student's conceptual understanding of difficult biology concepts such as photosynthesis. Conceptual change texts strategy is an instructional approach that provides knowledge transformation on a specific concept from scientific inaccuracy into scientific accuracy (Cepni & Emine, 2010). Balci, Cakiroglu and Tekkaya (2005) observed that these texts are carefully designed to create awareness in students' conceptual inadequacies and bring about conceptual conflict. This strategy according to Alkhawaldeh and Salem (2019) promotes conceptual change because it challenges students' alternative on a concept by producing dissatisfaction before the correct understandable and plausible explanation is presented.

Alkhawaldeh and Salem (2019) explored the utility of the conceptual change texts on students' understanding of concepts related to plants respiration and reported that it was useful in addressing students' misconceptions and improved conceptual understanding of student.

Another conceptual change instructional strategy reported to be effective for enhancing students' conceptual understanding of difficult scientific concepts is concept cartoons (Akamca et al., 2009; Gafoor & Shilna, 2013). Concept cartoons are reported as pictorial tools consisting of individuals normally three or four, proposing and debating on a particular scientific concept (Stephenson & Warwick, 2002). Concept cartoons are reported to elicit students' interest, promote discussion and facilitate student engagement in the classroom by prompting students to brainstorm and debate about the concept introduced by the characters (Gafoor & Shilna, 2013). Perales and Vilchez (2005) observed that the discussion and collaborative nature of this teaching approach does not only promote motivation but also facilitates practical work, reduces classroom mismanagement and provides a manageable way by which teachers can plan and conduct effective lessons. Gafoor and Shilna (2013) posit that concept cartoons challenges students to brainstorm to solve real life problems. Given the importance of photosynthesis to live of earth, it is important that effective teaching approaches (i.e., conceptual change texts and concept cartoons) are explored to help improve students' understanding.

Statement of the Problem

Photosynthesis, one of the main concepts in biology, is established to be difficult (Tlala, Kabirige & Osodo, 2014; Tekkaya, Oscan & Sugur, 2001) for students at the secondary school level and Ghanaian students are no exception (Sarpah, 2021). In particular, the West African Examinations Council (WAEC) Chief Examiners' report for Elective Biology for Senior High Schools in 2015, 2016, 2017 and 2018 for both regular and private candidates revealed students' poor understanding of concepts related to photosynthesis. For instance, in 2015, the Chief Examiner indicated students show inadequate understanding of the adaptation of a leave for photosynthesis and how to test for starch stored in a leaf. The report further revealed that most students avoid questions relating to photosynthesis and, those who attempt questions on the concept scored low marks. The chief examiner in 2017 revealed that students were unable to outline the procedure for testing for starch in a leaf. He further reported in 2018 that students demonstrate inadequate understanding of the process of photosynthesis.

Students' difficulty in understanding concepts related to photosynthesis have also been attributed to misconceptions they have on concepts relating to photosynthesis. For instance, majority of students have the misconceptions that photosynthesis is a gas conversion mechanism, and that photosynthesis is the reverse of respiration (Cokadar, 2012).

It has also been reported that students have the idea that the accumulation of organic matter in plants is merely as a result of water and inorganic matter coming from the soil and not due to the resultant effect of the process of photosynthesis (Esra & Ponar, 2010). Studies have also shown that most students think plants obtain their food directly from the soil by using their roots to absorb water and mineral salts (Mintzes & Wandersee, 2005). Additionally, it is also reported that students have the idea that the dark stage of photosynthesis continues in the absence of light (Parker, Anderson, Heidemann, Merrill, Merritt, Richmond & Lurain, 2012).

Tlala et al. (2014) posit that to alleviate misconceptions and to improve Conceptual change, it is very necessary for teachers to employ conceptual change instructional strategies including conceptual change texts, concept cartoons, concept attainment model and generative learning theory. In spite of the suggestion that difficult concepts such as photosynthesis should be taught using conceptual change instructional strategies, the concept still remains one of the problematic topics for Ghanaian senior high school students where the conventional teaching approach is mostly employed (Quainoo, Otami & Owusu, 2021). This conventional instructional approach seems not to be able to promote students' conceptual understanding (Ozmen, 2007). Therefore, it is needful to employ alternative teaching strategies that considers students' alternative conceptions that facilitates conceptual change. Among the conceptual change instructional strategies, conceptual change texts

(Alkhawaldeh, 2019; Balci et al., 2005) and concept cartoons (Akamca et al., 2009) have been reported to be very essential in diagnosing students' misconceptions and facilitating conceptual understanding. As noted by Akamca et al. (2009), concept cartoons and the conceptual change texts are effective in arousing students' interest, motivation and promoting student-student discussion.

It has been established from literature that concept cartoons and conceptual change texts are effective in addressing students' difficulty and improving their conceptual understanding in concepts related to photosynthesis. In spite of this discovery, these instructional approaches are commonly not used in teaching Biology concepts in SHS in Ghana (Sarpah, 2021). Previous studies on concept cartoons and conceptual change texts have mostly sought to compare the relative effectiveness of these instructional approaches with that of the Conventional approach without determining the extent to which these approaches had improved students' conceptual understanding of concepts related to Biology. More so, most of these studies failed to explore students' misconceptions regarding biology concepts. In view of this, this study sought to explore how concept cartoons and conceptual change texts instructions could be used to improve SHS student's conceptual understanding of concepts related to photosynthesis. Additionally, the study sought to determine the extent to which students' knowledge and understanding had improved (knowledge gain) when they were exposed to concept cartoons and conceptual change cexts instructions.

Purpose of Study

The purpose of this study was to explore the effectiveness of conceptual change texts and concept cartoons on Senior High School Students understanding of photosynthesis and to determine the extent of knowledge gain as well as exploring their misconceptions in Photosynthesis.

Research Questions

The study was guided by the following research questions:

1. Is there statistically significant difference in the mean pretest scores of SHS students' performance in photosynthesis before and after intervention using concept cartoons, conceptual change texts and conventional method?
2. What are Senior SHS students' view on the use of conceptual change texts and concept cartoons in teaching and learning of photosynthesis?
3. What are SHS students' preconceptions regarding photosynthesis?

Research Hypotheses

The following research hypotheses were tested:

$H_{01:}$ There is no statistically significant difference between students' prior knowledge in photosynthesis and their knowledge after been taught with concept cartoons, conceptual change texts and conventional method.

$H_{02:}$ There is no statistically significant difference in the mean posttest scores of students' performance between those taught using conceptual change texts, concept cartoons and the conventional teaching approach.

H_{03}: There is no statistically significant difference in the mean pretest and posttest scores of SHS students' performance in photosynthesis between high achievers and low achievers in the groups taught with conceptual change texts and concept cartoons.

Significance of the Study

Photosynthesis is generally considered a very difficult subject in Senior High Schools (Nas, 2010; Parker et al., 2012). This is shown in poor understanding and thus achievement in the concept. In view of this, the findings of this study will be very beneficial to teachers, policy and decision makers in education, and curriculum developers. First, the outcome of this study may bring to the fore, the effectiveness of conceptual change texts and concept cartoons in addressing students' misconceptions regarding photosynthesis. Second, the outcome of this study will inform policy and decision makers such as Ghana Education Service (GES), Ministry of Education (MoE) and curriculum developers to consider recommending conceptual change test and concept cartoons as a teaching approach for teaching concepts related to photosynthesis. Finally, the lesson plans developed based on the instructional approaches used in this study could be adopted to facilitate conceptual change in students regarding concepts related to photosynthesis.

Delimitations

Although there are several topics that research has shown that Senior High School students show conceptual difficulties, nevertheless this study was delimited to only photosynthesis. This is because it is not possible for the study to cover all the difficult concepts in biology.

Also, all SHS Schools in Ghana could not be covered in this study because it was not feasible to do so. Therefore, only three schools from the Jomoro and Ellembele Municipality were selected to participate in this study. Further, only Form 3 students of SHS were used for the study. Finally, only conceptual change texts and concept cartoons were used in this study in spite of the fact that several conceptual change approaches are been found to be effective in enhancing conceptual understanding of students.

Limitations

The researcher had no control over some extraneous variables like students' maturation, previous experience and their ability. These extraneous variables can affect the results of this study. The findings of this study cannot be generalised for all the SHS in Ghana except the schools in the Jomoro and Ellembele Municipality that were used in this study. This is because not all form three science students in the country were used.

Definition of Terms

Misconception: is an incorrect view or opinion held by someone due to faulty thinking or understanding (Wandersee, 2005).

Conceptual understanding: Conceptual understanding describes the learning process that builds upon a student's alternative conceptions of concepts to the correct concepts (Duit & Treagust, 2003).

Photosynthesis: Photosynthesis as a biochemical process by which sunlight energy is utilized through series of enzyme catalyzed reaction to convert inorganic molecules such as carbon dioxide (CO_2) into organic molecules (Ray & Beardsley, 2008).

Conceptual change texts: Conceptual change texts are texts carefully designed to arouse students' preconceptions, introduce common misconceptions and help students better understand scientific explanations that are plausible and intelligible (Armagan et al., 2017).

Concept cartoons: concept cartoons are visual drawings or interesting pictorial tools designed in the form of cartoons where the characters in the cartoons presents ideas, debate or argue about a particular concept whereby each character in the cartoons defends his or her viewpoints regarding a particular concept (Akamca et al, 2009).

Organization of the Study

This research is put into five chapters with each chapter dealing specifically with an aspect of the study. The chapter one focused on the background to the study, statement of the problem, purpose of the study, research questions, significance of the `study, delimitations, limitations and definition of terms. Chapter two highlighted related literature review which consisted of theoretical framework and other aspects of literature considered essential for the study. Research design, population, sampling procedure, data collection instruments, data collection procedures and data processing and analysis were covered in chapter three. Chapter four covered presentation of results and discussion of the results obtained. Chapter five ended the study which focused on summary of the study, conclusions, recommendations and suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

Overview

This study aimed at exploring the effect of concept cartoons and Conceptual change texts on Senior High School students' conceptual understanding in concepts related to photosynthesis. Literature relating to the aim of the study were reviewed with respect to the research questions and hypothesis that guided the study. First, theoretical perspectives underpinning the study, misconceptions regarding concepts relating to photosynthesis, conceptual change and conceptual change model were reviewed. Again, implications of conceptual change theories were looked at. important teaching strategies (concept cartoons and conceptual change texts) based on conceptual change models were reviewed. Impact of concept cartoons and conceptual change texts on achievement levels of students were reviewed. Finally, literature was reviewed on students' perception on instructional approaches. Based on the review, a theoretical framework based on Piaget theory of constructivism was developed to guide the research.

Theoretical Framework

This study hinged on Piagetian Constructivism which is regarded by science educators as one of the major theories in education which stipulates that learners build their own understanding of the world by testing ideas and approaches based on their prior knowledge and experiences (Tuera, 2019). Constructivism according to Bada and Olusegun (2015) is as an approach in which the central principle emphasize that learners make use of their existing understanding only to make sense of new situations. Thus, unlike behaviorism, learning according to constructivism considered as an active process whereby students construct meaning by connecting fresh ideas with previously existing ones. Therefore, constructivists maintain that students in the learning environment actively produce knowledge in response to their association with their previous knowledge and environment (Cakir, 2008). This means that teachers are not dispenser of knowledge as observed in the case of the behaviorists. However, students are provided with several opportunities and incentives to construct their own knowledge base on their previous knowledge and experiences. Constructivism educates that, the students' existing knowledge should first be considered by teachers and be motivated to put that knowledge into practice (Kong, & Song, 2013). While the Behaviorist school of thought may help teachers understand what students are doing, constructivism suggest that teachers rather need to know what students are thinking and discover new strategies for assisting them achieve conceptual change (Adu-Gyamfi, 2014). Therefore, constructivism encourages teachers to find ways of eliciting and dealing with students' misconceptions in difficult concepts for meaningful learning to take place.

Jean Piaget and Lev Vygotsky are considered as the two important proponents as far as the development of the constructivist theory is concerned (Cetin-Dindar, 2016). Jean Piaget is noted for cognitive constructivism whereas Lev Vygotsky is the proponent for social constructivism. The main focus of Cognitive constructivism lies on how the individual student comprehends things in accordance with developmental stages and learning styles whiles the goal of social constructivism is to determine how meaning and understanding emerge out of social encounters (Cakir, 2008). Because prior student conception is an important component of Piaget’s theory of constructivism and best provides opportunities for conceptual change, Piaget’s theory of cognitive constructivism derived from the notions of assimilation, accommodation, and disequilibrium (Tuera, 2019) was considered a better framework for this study. Therefore, understanding of the theory of constructivism is essentially significant for teachers and other educators in Ghana to understand misconceptions, how they originate, and why they are difficult to alter.

According to Piagetian constructivism, learning is an active process of Conceptual change whereby students deconstruct their already existing alternative conceptions with the correct scientific concepts as they form new preferred connections in their conceptual framework (Posner, Strike, Hewson, & Gertzog, 1982). Piaget’s notion of conceptual change is based on assimilation, accommodation, and disequilibrium (Roya & Davatgari, 2015). He proposed that in assimilation stage, the student construct new ideas to be learned through generalization upon previous scientific ideas. Thus, assimilation helps the student to embrace new occurrences into his or her old experiences. The resultant effect is that the individual student comes to develop new interpretations which helps him or her rectify what was once misunderstood and judge what is important. Accommodation, according to Piaget, is the reframing of one’s worldview and new occurrences into his or her existing conceptual framework. In accommodation stage, students build new scientific concepts to be learned through discriminating from their prior existing alternative conceptions (Posner et al., 1982). Liu and Lan (2016) proposed that accommodation can only occur when a student is brought to the point of dissatisfaction with a preexisting scientific concept and therefore becomes ready to accept a more intelligible, plausible, and fruitful concept.

Piaget's theory of constructivism is considered important theoretical framework for this study because of its educational impact and far-ranging connections and suggestions for developing, planning, implementing, evaluating curriculum and instructional management in schools. According to Piaget, the ultimate focus of education is to produce students who have the capability to create and innovate or take initiatives and are self- discovering without depending on others. In view of this, Piaget suggests that during the initial stages of learning, teachers create a conducive and rich environment for students to explore on any field. In view of this, teachers are encouraged to involve interesting materials that can make students more active in the classroom so that they can become constructors of their own knowledge through their experiences (Zembylas, 2005). Another significant implication of Piaget's theory in facilitating conceptual change is that teachers should act as facilitators in science classrooms whose responsibility is just to furnish or supply students with the requisite possibilities to test their current level adequacy. To this end, teachers are to find effective ways of challenging students' knowledge in order to make them effective critical thinkers and problem solvers (Adu-Gyamfi, 2014).

Concept of Photosynthesis

Photosynthesis is considered the most important and interesting biological concept that has attracted greatest concern from Biologists all over the world (Sodervik, Mikkila-Erdmann & Vilppu, 2013; Nas, 2010; Kurt et al., 2007). This unique and fundamental concept has drawn the committed research attentiveness of numerous researchers from various authorities across the world (Svandova, 2013). All over the world, Biologists agree to the fact that Photosynthesis is the most basic (Dimec & Strgar, 2017) and the most significant (Marmaroti & Galanopoulou, 2006) biological process on earth (Kurt et al., 2013). And from the perspectives of the functioning of the ecosystem, it is naturally regarded as the most important biological processes on earth. In view of this, it has always been recommended as one of the essential topics in SHS Biology curriculum (Barrutia & Diez, 2019). Because of the basic and fundamental nature of this concept, the international comparative study Trends in International Mathematics and Science Study (TIMSS) have often incorporated concepts related to photosynthesis, which substantiate the importance of this concept in the mandatory content of school curriculum all over the world including Ghana (Dimec, 2017). Photosynthesis is a concept that has been associated with the survival of life on earth and the stability of an ecosystem due to the fact that it forms the basis for survival directly or indirectly for almost all known living organisms all over the world (Esra & Ponar, 2010). As claimed by the Ecologist, the process of photosynthesis is the primary source of energy on earth, explaining that plants capture the sun's energy through the process of photosynthesis which is used to manufacture complex and energy-rich molecules such as sugars from molecules of carbon dioxide (CO_2) and water (H_2O) (Koba & Tweed, 2009**)**. Therefore, these manufactured food molecules directly or indirectly serve as the primary source of energy for the plants themselves and ultimately for all living organisms on earth including decomposers, fungi and bacteria (Kurt et al., 2013). The only exceptions, according to literature and scientific data are organisms that live in extreme environments such as deep Ocean where their mode of survival depends on chemosynthesis (Dimec, 2017). Photosynthesis is not only important for stabilizing the ecosystem through energy production, it is also necessary for maintaining the normal level of oxygen in the atmosphere. Thus, this important biological process helps mob excess carbon-dioxide (CO_2) from the atmosphere and renew the oxygen (O_2) content thereby leading to the reposition of photosynthetically acquired carbon as algal, bacterial and plant biomass (Ekici et al., 2007). Consequently, the accumulating effect of photosynthetic organisms is accountable for biochemical conversion of approximately two hundred (200) billion tons of CO_2 into carbohydrates every year (Esra & Ponar, 2010). Therefore, in Ghana, it is popularly said that when the last plant dies, the last man also dies. This statement confirms the importance people ascribe the concept of photosynthesis as an important process for the survival of life on earth.

Ray and Beardsley (2008) defined photosynthesis as a biochemical process in which carbon dioxide is converted to organic molecules by using energy obtained from the sunlight. Basically, photosynthesis points to a process that starts in the cell and continues at the global level (Kurt et al., 2013). In

Ghana, the concept of photosynthesis occupies a central place in the school curriculum. According to the school curriculum, students in Ghana begin to learn the basic concepts in photosynthesis in basic school and continue at the SHS. In the SHS Elective Biology Syllabus, photosynthesis is included in the section 'Plant structure and physiology'. Tekkaya et al., (2008) suggested that it is increasingly significant for everyone to adequately understand the numerous impacts of photosynthesis on their daily lives if they will appreciate the essence of learning this concept particularly in the classroom. Therefore, he maintained that a proper understanding of this concept is needed as far as discussion of autotrophic organisms or the factors that impact the distribution of life on earth. Cokadar (2012) also suggested that a useful understanding of this concept to a large extent will serve as the foundation on which students can build their understandings regarding cycling of matter and energy flow in an ecosystem, as well as improving their understanding about the interdependence of life on earth. Dimec (2017) proposed that knowledge about photosynthesis is essential because it equips students with the understanding of how the world functions as an ecosystem and how it acts as a bridge between the non-living and living worlds. Tlala et al., (2009) indicated that a fundamental understanding of this concept is also needful for students to build a useful understanding of critical useful naturally occurring patterns such as energy pyramids. Ray et al., (2008) were of the view that understanding of this concept is even more important nowadays for people to understand this important biological process responsible for most vital human and economic issues on earth, such as depletion of nonrenewable fossil energy, sources of hunger and climate change. Therefore, for citizens in a particular country to plan or take important decisions with respect to the above-mentioned issues, thorough training regarding this important process whiles undergoing secondary education (Barrutia & Diez, 2019). Consequently, students underdoing secondary education are supposed to thoroughly understand this process (Cokadar et al., 2012) and be able to explain photosynthesis in light of how plants link soil and water with the atmosphere and how carbohydrate is produced and becomes biomass by utilizing the sunlight energy, CO_2 and water (Ray et al., 2008). From the foregoing, it is understandable and justified why photosynthesis is included in the Elective Biology curriculum in Ghana.

In spite of the fact that photosynthesis is a compulsory aspect of the science curriculum in Ghana, several studies have proved that it presents a serious conceptual challenge to students at all levels of education (WAEC, 2014; Ray et al., 2008; Barrutia et a*l*., 2019). According to science literature, there are a large number of studies that have shown students' learning difficulties regarding photosynthesis (Kurt et. al, 2013; Koba Tweed, 2009; Dimec, 2017; Marmaroti & Galanopoulou, 2006).

For the past decades, researchers in Science Education have identified several causes of students' difficulty regarding this concept. According to Kurt et al., (2013), this concept is a difficult for students to grasp because of its involvement in complex transformations and biochemical processes and its interrelationship with several other disciplines such as biochemistry, ecology, physiology and many others.

Tlala et al. (2014) are of the view that students consider this concept difficult because the real outcome of this biological process poses a challenge to students when it comes to its analysis mainly because the rate of growth of plants is apparently slow and difficult to visualize the process. The lack of requisite resources in some SHS also contribute to students' difficulty in understanding concepts related to photosynthesis. For instance, in schools where laboratory equipment are unavailable for students to gain hands-on teaching, students would find it very challenging to conceptualize the process. Photosynthesis according to Russell et al., (2004) is a concept that cut across disciplines including biochemistry, respiration, ecology and organizational levels. Therefore, for students to fully understand this concept, they need adequate knowledge and understanding in these disciplines to facilitate their understanding. Besides, students need fundamental understanding of words and descriptions of basic processes involved in photosynthesis such as light harvesting, the electron transport chain, oxygen evolution and carbon fixation (Russell et al., 2004).

In addition, to fully understand photosynthesis, students should be able to understand the integration and the interrelationships existing between transformation of energy and aspects of plants that are observable (Kose & Uşak, 2006). It is reported that, students in SHS find it challenging in understanding energy transformation for two major reasons. The first reason is that, the process involved in light energy transformation into chemical energy during photosynthesis is considered unobservable hence abstract. Secondly, chemical reactions occurring between carbon dioxide and water molecules requiring light energy is involved in energy transformation (Marmaroti & Galanopoulou, 2006).

Therefore, for students to adequately understand the link between photosynthesis and energy transformation, they are required to have the understanding that what provides the activation energy for the reaction between carbon dioxide and water molecules is light energy. Thus, light energy is utilized in breaking the bonds of the molecules that initiate a reaction which ultimately leads to the transformation of energy in plants (Cokadar et al., 2012).

Misconceptions about Photosynthesis

The presence and persistence of misconceptions has largely been accoutered as one of the main causes of students' difficulty in understanding this concept (Barrutia et al., 2019). Over the years, researchers in various academic disciplines have spent significant amount of time researching into misconceptions in science education (Esra & Ponar, 2010). It is widely published that learners at every stage of education hold diverse views on science concepts related to photosynthesis before actual instruction which in most cases conflicts with the idea which is scientifically acceptable and plausible (Koba & Tweed, 2009; Svandova, 2013). It has been established that although students are taught starting basic school, they still have misconceptions about photosynthesis (Tekkaya & Balci, 2003; Esra & Ponar, 2010) and these misconceptions even at an early stage of education occur and are reinforced as they advance in their education (Barrutia et al., 2019). Thus, misconceptions are widely spread and deeply rooted. It is also well known that misconceptions students develop as they climb up the educational ladder are often prevalent and very challenging for students to overcome through conventional teaching approach (Svandova, 2013).

Ray et al., (2008) pointed out that student misconceptions before or after class discussion should become a major concern for researchers in science education because they influence how students learn new scientific knowledge and play a significant role in subsequent learning, and can become a major obstacle in facilitating conceptual change (Dimec et al., 2017). It has been established that the ease at which a particular topic could be learnt by students is largely determined by the nature and quality of pre-existing conceptions students already hold. Thus, previous knowledge is in agreement with the new concept being learnt, it facilitates learning. Similarly, if the previous knowledge does not agree with the new concept they are currently introduced to, it may interrupt the leaning process (Sodervik et al., 2014). Therefore, inaccurate previous knowledge can present a serious challenge to instructors and students during the teaching and learning process of abstract scientific concepts such as photosynthesis.

There are several possible sources from which prior ideas and misconceptions could arise (Barrutia et al., 2019). Misconceptions most often arise as a result of poor understanding of biology concepts when students do not create a proper association with new scientific concepts presented by teachers (Nas, 2010). Thus, when new concept is not meaningful or intelligible to students, their knowledge remains unchanged and further hinders their understanding (Svandova, 2013). Misconceptions can also arise from misinterpretation of one's experiences in life (Mintzes & Wandersee, 2005;

Sodervik et al., 2014; Koba & Tweed, 2009). Some of these misconceptions originate as a result of students' direct personal experiences they have had previously from experiencing how plants grow. Therefore, even though photosynthesis is a productive natural mechanism occurring in green plants, it has been noted by Esra (2010) that the process involved in nutrients production process of plants contradict with the nourishment concept already occupying the minds of students, and this is so because of their previous experience with plants as they grow up. For instance, some students have the perception that the soil is the source of all the nutrients required by the plant. This idea seemingly harmonizes with their everyday experience with plants because when fertilizers are applied to the plant, the plant absorb the dissolved fertilizer and mineral salts through the roots hence their misconception that plants obtain their food through the soil (Kose, 2008; Mintzes & Wandersee, 2005).

Given the extensive views regarding the essence of understanding the concepts related to photosynthesis, it is important to know that many researchers have made great efforts in an attempt to determine what misconceptions students have regarding photosynthesis. A comprehensive study was made by Marmaroti and Galanopoulou (2006) about students' understanding of photosynthesis where they observed several areas of photosynthesis including, physiology, photosynthesis and energy, photosynthesis as a chemical reaction, photosynthesis and plant feeding, photosynthesis and respiration, and photosynthesis and the function of the ecosystem. They concluded that students do not demonstrate correct understanding of how energy is transformed and also lack proper understanding of photosynthesis for instance, the function of chlorophyll in the process of photosynthesis and hence they find it difficult to see the process as a chemical reaction. Marmaroti and Galanopoulou (2006) and Kose (2008) observed that students lack proper understanding of the function and location of chlorophyll in plant. For instance, Marmaroti and Galanopoulou (2006) observed that some students consider the pigment in plant produced during photosynthesis is either a reactant or end product of photosynthesis. Additionally, some students are of the view that the dark stage of photosynthesis can take place even in the absence of sunlight (Parker et al., 2012). Similarly, a study was carried out by Tekkaya and Balci (2003) with the intention to determine the misconceptions SHS students have regarding concepts related to photosynthesis and respiration in plants. They noted that most of the students considered the process of photosynthesis of a gas productions mechanism and thought the reverse of photosynthesis is respiration. In a study by Haslam and Treagust (1987) where they investigated misconceptions held by thirteen (13) to seventeen (17) year old Australian students using two-tier diagnostic test instrument, it was revealed that a majority of SHS students find it difficult to understand the connection existing between photosynthesis and respiration in plants. The studies by Amir and Tamir (1994) indicated students have misconceptions about the organic substances produced by plants. They also reported that a vast number of students hold that the mass increase of plants is merely as a result of accumulation of inorganic matter and water from the soil. A study by Svandova (2013) also revealed that students have varying ideas regarding the functions of sunlight, products and reactants in photosynthesis. He established from his studies that students have the misconception that sunlight is a material which is incorporated into the plants' mass as opposed to being the main energy source of photosynthesis driving the reaction of photosynthesis. Kose (2008) clearly pointed out that some students do not even understand that the major contributor to plant biomass is carbon dioxide (CO_2) is also lack the understanding of the fact that glucose apart from functioning as the source of building blocks for cell growth, also serves as storage of energy. Sodervik et al., (2014) also observed that students perceived all that was needed for the process of photosynthesis was simply the conversion of carbon dioxide (CO_2) and water to carbohydrate and oxygen. They further reported that majority of students believed that the green color of plants is due to a green light they absorb from the sun.

Parker et al. (2012) proposed that the greatest cause of confusion for students regarding photosynthesis is that students do not understand the differences between photosynthesis and cellular respiration and often one with each other. They are of the view that majority of students have the knowledge that plants do not undergo respiration hence the means by which plants respire is photosynthesis (Kose, 2008; Amir & Tamir, 1994), or that photosynthesis provides the energy directly needed by the plant (Tekkaya et al., 2006; Kose, 2008). Parker et al., (2012) noted that some students at times confuse the process of respiration with breathing and conceptualize respiration as a gas-exchange process. Because certain reactants of photosynthesis such as carbon dioxide and water are also the products formed after respiration has taken place and because oxygen is a reactant of respiration, respiration is often considered as the opposite of photosynthesis. Research shows that students do not seem to understand the different chemical pathways involved in the two processes and their locations in the plant (Sodervik et al., 2014; Tekkaya, 2006).

Conceptual Change in Science Education

Conceptual change occupies a central position in learning (Abdul & Akhilesh, 2010) and has become an important area of studies concerning teaching and learning over the past decades, and is regarded as a tool that can gradually bring transformation to science education and help move it nearer to the empirical and theoretical work on concept learning, conceptual development, conceptual evolution in philosophy, cognitive science and psychology, (Treagust, Duit & Widodo, 2008). Arriving at a conceptual change is an important step for systemic understanding of abstract concepts such as photosynthesis (Troyer, 2011) and this requires that, students are assisted to reorganize their previous fragmented knowledge structures (Sodervik et al., 2014). In view of this, it is the aim of science education to support students arrive at conceptual change and receive step by step understanding of science concepts.

Conceptual change has been extensively studied over the last decades due to the numerous misconceptions that students develop based on everyday life, intuitive thinking, their personal experiences and social media influence (Nadelson, Heddy, Jones, Gita, & Johnson, 2018). Thomas Kuhn's works on Theory change in the history and philosophy of science in 1962 forms the basis for conceptual change strategy to learning. According to Kuhn, normal science exists only under a set of assumptions, commitments, shared beliefs, commitments and practices that form paradigms. However, as new scientific findings or facts are discovered over a period of time, they may not be able to be accommodated within the existing paradigms. And according to Him, when those inconsistencies build up over time, a period of crisis is entered by science and in such situations, revolutionary change in paradigms becomes the only solution. Therefore, when there is a paradigm shift, there is conceptual change (Kuhn, 1962).

There have been several definitions and interpretations concerning the meaning of Conceptual change. Posner et al. (1982), defined conceptual change as a complex process by which the existing knowledge structure of a student is reorganized. Conceptual change emphasizes learning processes that builds on a student's preexisting conceptions of science to the correct and acceptable new concepts (Duit & Treagust, 2003).

From the standpoint of Sodervik et al. (2014), conceptual change does not necessarily mean just replacing previous inconsistent conceptions with the scientifically accepted ones. Instead, it involves the process whereby a new conceptual space is opened. Agiande et al. (2015) described conceptual change as a social process whereby individuals in a socio-cultural context interpret their experiences based on existing knowledge. Thus, they consider conceptual change as a usual social interaction between a student and a teacher where the two actively participate in exchanging ideas. Posner et al. (1982) consider conceptual change theory as a means of recognizing students' previous misconceptions which they bring into the classroom so as to enable them exchange the wrong conceptions or add new ones which are more plausible, intelligible and useful and not just a mere sociocultural interaction or a teaching strategy.

For conceptual change to be achieved successfully, the student is required to be made aware of the differences between his or her preexisting conceptions and the correct scientific conceptions and must be ready to make changes in his or her conceptions to better reconcile with the scientifically accepted concept (Posner et al., 1982). This however poses a serious challenge to students particularly regarding certain phenomena experienced every day because students' prior conception seemingly possesses strong interpretive power, hence it would demand hard work in order to change them (Duit & Treagust, 2003). Sometimes, conceptual change becomes extremely challenging to occur since certain ideas achieved through every day experiences are sometimes so powerful to the point that it becomes tedious to reject and accept a new one. Consequently, systematic study and instruction are often required for conceptual change to occur (Sodervik et al., 2014).

Hewson (1982) identified that due to the web-like connections formed in the conceptual ecology of the student, misconception often perverts, confuse and limits learning and is not easily to be changed. Subsequently, a student requires a corresponding change in the other related concepts in ways that resemble a kind of paradigm shift in order for conceptual change to occur. This means that teaching targeting conceptual change requires that teachers engage students systematically so as to help them reject their scientifically incorrect ideas and accept new ideas which are scientifically acceptable (Vosniadou, Vamvakoussi, & Skopeliti, 2008).

To achieve conceptual change, researchers maintain that the misconception that conflicts with the correct scientific conception must be determined so that the student is made aware of his or her wrong conceptions (Braach, Goldman & Wiley, 2013). This involves helping students correct their misconceptions and helping them restructuring their naive conceptions into correct and acceptable ones whiles assisting them build intellectual tools useful for them in a variety of contexts (Amponsah & Ochonogor, 2018).

For the new concept to be assimilated or accommodated, Posner et al. (1982) emphasized that, the new concept must be intelligible (clear enough), plausible (reasonably true) and fruitful (potentially productive). He and his associates additionally suggested that these cognitive conditions are very crucial during the learning process even as the teacher guides the students in the direction of building cognitive conflicts for the sake of making students become dissatisfied with their existing knowledge (Abdul et al., 2010). From the point of view of Posner et al., (1982), conceptual change is only possible when a student comes across an event and then realize that his or her existing understanding is not sufficient to provide satisfactory or complete explanation. The discrepancy in knowledge creates the provision for the kind of dis-equilibrating event that evoke the dissatisfaction in students (Amponsah & Ochonogor, 2018).

Posner et al. (1982) proposed four underlying conditions necessary for conceptual change to occur. Firstly, the student must be dissatisfied with his or her existing concept. Secondly, the new concept introduced by the teacher must be intelligible. Also, the new concept must appear to be plausible, and lastly, the new concept must suggest the possibility of a fruitful idea (Ozdemir &

Clark, 2007). Intelligible in this regard denotes that the new concept presented must be clear enough to make sense to the student. Plausible means the new concept must appear to be true to the students. Fruitful means the new concept presented must appear to be useful or productive to enable the students solve emerging problems in their personal lives and the society at large. In view of this, Posner et al. (1982) proposed that the purpose of teaching is to create a cognitive conflict in order to make students dissatisfied with their existing conceptions so that they can receive the scientifically accepted concept as intelligible, plausible, and fruitful (Ozdemir et al., 2007).

Theoretical Perspectives of Conceptual Change

Studies of the philosophy and history of science have to a greater extent influenced how knowledge is constructed and perceived with regard to Conceptual change. For the past decades, scientists in science education have established various theories and models emerging from different philosophical stand points in an attempt to explain the origin and the nature of conceptual change. These theoretical perspectives of conceptual change emerged because of the difficulty students face in understanding certain difficult and abstract scientific concept including photosynthesis. Whereas some researchers explain the nature of conceptual change from the epistemological perspectives, others also build their explanations from the ontological and the affective perspectives. These theoretical perspectives are very important to be understood in science education because they form the foundation and the framework on which all other conceptual change models are built (Treagust & Duit, 2008).

Treagust et al. (2008) contended that conceptual change perspectives have the ability to a greater extent improve upon the teaching and learning activities, hence the need for science educators to grasp full understanding to be able to help students arrive at conceptual change. From science literature, the two most popular but opposing theoretical perspectives are the epistemological and the ontological conceptual change theories. Unfortunately, the affective domain has received very little attention with regards to conceptual change. From an epistemological and ontological perspectives, conceptual change implies the students' personal opinion on the nature of knowledge construction and on the nature or reality (Treagust et al., 2008).

An epistemological perspective of conceptual change

The influence of epistemological beliefs in science classroom and how students view and manage their knowledge has attracted the dedicated research interest of many science educators. The philosophical nature of knowledge and the process of knowing is referred to as epistemology (Agiande et al., 2015). Previously, epistemological conceptual change required only an understanding of evolution of students' conceptions. However, over the years, conceptual change from this perspective has also focused on an understanding of how students' conceptions evolved (Abdul et al., 2010). Constructivist ideas later progressed by merging various cognitive approaches where knowledge was primarily viewed as being constructed (Treagust et al., 2008). For instance, constructivist ideas combine Piagetian concept of assimilation and accommodation, Kuhn's ideas of theory change in the history of science and radical constructivism in order to explain conceptual change (Posner et al., 1982). Constructivism does not only emphasize on knowledge construction but also lay much emphasis on the significance of the social setting for the individual construction processes (Treagust et al., 2008). The epistemological assumptions by Constructivists also implies that for teachers to understand students' cognitive development, they should also try to gain deeper insight into how the constituents of the students' conceptual ecology interconnect and develop and how the conceptual ecology links with experiences (Abdul et al., 2010).

An ontology perspective of conceptual change

Although epistemology view of knowledge on the process of conceptual change has attracted several attention and support from the domain of science education, nevertheless majority of scientists have viewed knowledge from an ontological perspective (Carey, 1985). These researchers argue that scientists who explain conceptual change from the perspective of epistemology overemphasize how do not take into consideration how students view reality. Therefore, specific ontological terms are used by scientists from the ontological perspectives to explain changes in the way students view reality and how the nature of science concepts is viewed by students (Ozdemir et al., 2007). Thus, conceptual change from ontological perspective lay emphasis on the way students view the nature of the concept being presented and also attempts to assess how students view the scientific concept from their views of reality (Treagust & Duit, 2008).

Treagust et al., (2008) insisted that in some cases, there are discrepancies between the child's concepts and that of the adult because there are several scientific concepts which are inconceivable to the students' material conceptions hence making it challenging to make changes in students' ontologies in science classrooms. To this end, conceptual change in science classroom requires an ontological shift in how students perceive the nature of certain biological concepts such as photosynthesis (Chi, 1992). However, this ontological shift is sometimes difficult to achieve by students for two major reasons. The first reason is that the student may assign the new concept presented to a different ontological category from the scientific one. Secondly, the new concept may not be assigned because she or he may be lacking the actual knowledge structure required for that. Therefore, it is only when students come to the realization of their ontological commitments that they appreciate how the new scientific concept is incommensurable with their existing knowledge structure. When this occur, the student now makes the attempt to reassign the new concept into a correct knowledge structure by way of modifying his or her ontological presuppositions, categories and commitment (Chen & Wang, 2016). Lewis (2009) explained that it is difficult to achieve conceptual change in students due to the fact that very young children build their own theories and have speculations about everyday experiences. According to him, children believe based on the instruction, observations and experience from their daily life. Therefore, student's cognitive structures are constrained by their naive framework of presuppositions.

Affective perspective of conceptual change

The third perspective of conceptual change is the affective domain consisting of motivation, emotions and social aspects including group work which in the epistemological and ontological domain has been given little attention. Pintrich, Marx and Boyle, (1993) strongly contended that students' individual's goals, control beliefs, self-efficacy and classroom social context, purposes, needs, expectations and intentions are as significant as cognitive strategies in concept learning. Similarly, Simatwa (2010) advanced that group factors have advantage in bringing about a conceptual change. Another theory that lays emphasis on the importance of social and motivational importance in facilitating conceptual change is the Vygotsky's theories (Lewis, 2009). Pintrich et al. (1993) demonstrated that interest, personal and situational beliefs are important for students' participation in learning activities. They further contended that teachers who fail to take into consideration the affective, social, personal and group learning place limitation on conceptual change. Thus, in order to link the cognitive and the emotional in teaching and learning of science concepts, Zembylas (2005) argues that it is necessary to develop a unity between the cognitive and emotional dimensions where emotions is not only perceived as a moderating variable of cognitive outcomes but as a variable of equal status. Chen and Wang (2016) indicated that students' self-efficacy and control beliefs, classroom social context together with his goals, expectations and needs are important cognitive strategies in bringing about conceptual change. Additionally, they emphasized that Students' beliefs, models and theories influence to a large extent by social, personal, historical, motivational and situational beliefs. Therefore, they proposed that the background knowledge of students most at times limit the knowledge restructuring. Consequently, science educators or teachers who ignore the social and motivational factors in learning and teaching activities will cause limitation in the students' knowledge restructuring (Amponsah & Ochonogor, 2018).

Conceptual Change Model (CCM)

It has already been established that conceptual change is key to learning science. Nonetheless, it can be very challenging to achieve especially in science education where majority of the concepts are counter-intuitive, controversial and abstract. This then suggests that science teachers and researchers in science education construct the right models deemed necessary for addressing and investigating conceptual change. Conceptual change from the perspectives of epistemology, ontology and affective have provided a powerful framework for the emergence of several models developed by researchers in science education to address students' misconceptions in difficult concept and to help them arrive at conceptual change (Treagust et al., 2008). Some researchers based their conceptual change theories in terms of Piaget's notion of assimilation and accommodation or Kuhn's notion of a paradigm shift or combination of both (Ozdemir et al., 2007). Example of popular conceptual change theories include the Conceptual Change Model (CCM), Cognitive-Affective Model of Conceptual Change (CAMCC), Cognitive Reconstruction of Knowledge Model (CRKM) and Dynamic Model of Conceptual change (DMCC).

One of the most prominent conceptual change models derived from Kuhn's notion of a paradigm shift and Piaget's notion of accommodation was defined by Posner et al. (1982). In their study, they emphasized that if a student's current conception is functional and can solve problems within his or her existing conceptual schema, then the student does not feel the need to alter the current conception. However, when the student's current conception does not successfully solve some problems, the student may make only little changes to his or her conceptions. This moderate change in students' conception according to Hewson (1981) is called conceptual capture or weak restructuring. In such situation, assimilations occur without any need for accommodation though it is believed that the learner must first be dissatisfied with an initial conception in order to ignore it and accept a scientifically accepted conception before successful conceptual change can occur. When a more radical change occurs, it is referred to as conceptual exchange or radical restructuring (Nadelson et al., 2018).

According to Hewson and Hamlyn (1984), the conceptual change model is categorized into two main aspects. The first category is the conditions that must be satisfied before a person can experience conceptual change. The second component is the conceptual ecology of the student that provides the context in which Conceptual change occurs. The necessary conditions according to Agiande et al. (2015) that must be fully satisfied to bring about conceptual change are: dissatisfaction, intelligible, plausibility, and fruitfulness which are explained further in this review.

(1) Dissatisfaction: Until students have sufficient reasons to abandon their existing conceptions, it does not seem easy for them to accept the new concept presented to them in the classroom. Therefore, one primary objective of a teacher is to intentionally cause dissatisfaction in students' existing conceptions by identifying and proving their initial conceptions to be wrong. When students are now dissatisfied with their preexisting conception, that is

when they are ready to accept the new concept which must be intelligible (Posner et al., 1982).

(2) Intelligible: students would either consider correcting their existing concept or ignore the difficult concept and maintain their original concept if the new explanation is not clear and reasonable. Hewson (1982) proposed for a new concept to make sense to students, these questions must be answered by teachers: did the student understand its meaning? Can the student find a way to represent this concept? Thus, if students consider a particular concept to be understandable, they must be able to explain and to present this concept in ways they are familiar with and not just reproducing or repeating what the teacher presented. According to Ozdemir et al. (2007), descriptors for intelligible include "I must know what the new concept means – the concept must be understandable and the concept must make sense as well" (p 121).

(3) Plausibility: Even when comprehensible examples were provided for explanation, students would still fail to understand if the given example seemed unreasonable to them. Therefore, Hewson (1982) suggested that in order to make students think a concept is plausible, it is vital to know whether students consider the new knowledge to be true. Therefore, the teacher must ask himself/herself whether the new concept is consistent with other concepts that the students are already familiar with. Accordingly, to make the students feel credible and reasonable, the new concept must without any conflict, coordinate with what students have already accepted as true. According to Treagust et al., (2008), descriptors for plausible include "it first must be intelligible, it must fit in with other ideas or concepts I know about or believe" (page 121).

(4) Fruitfulness: the last condition that must be fulfilled for conceptual change to occur is fruitfulness without which students' conceptual understanding would not be complete. Therefore, Hewson (1982) proposed that to make students accept a particular concept as fruitful, the teacher must question himself/herself the following: what value will my students gain from this new concept? Can this new concept address problems that students failed to solve? Will this new concept give students a new direction or idea? In a nutshell, to make students think a new concept is reasonable and beneficial, it should have the capacity to solve problems that other concepts they are already familiar could not, and make them realize the importance of the new concept being presented. According to Treagust et al. (2008) descriptors for fruitful include "it first must be intelligible; it should be plausible and I can see it is something useful – it will help me solve problems" (p. 122). Chen and Wang (2016) classified the above three conditions—intelligible, plausible and fruitful as a person's conceptual status. Thus, the degree to which the new concept fulfills the three conditions mentioned above is termed as the status of a person's conception. Also, the status of one's conception is directly proportional to the extent of the conditions that are met.

Apart from the conditions that needs to be satisfied, the person's conceptual ecology forms the second context for conceptual change to occur. Student' conceptual ecology contributes significantly in determining the status of a person's conception since it provides the conditions for students to decide whether a given condition is either met or not (Troyer, 2011). The conceptual ecology consists of many diverse forms of knowledge that forms the structure for new information to occur. This knowledge includes the epistemological commitments involving consistency or generalizability, metaphysical beliefs about the world such as the nature of time, and analogies and metaphors (Hewson, 1982). To determine whether different criteria are met, students make use of their existing knowledge (their conceptual ecology) to determine if all the three conditions are met (Ozdemir, 2008).

A major proposition concerning conceptual change model is that, conceptual changes are not possible to achieve without the accompanying changes in the relative status of changing conceptions. In view of that, to successfully learn a new concept, its status must rise for a student to understand and accept it as fruitful. However, if the student contradicts a current concept with an old one which already has a higher status for the student, the student will find it difficult to accept it unless the status of the existing concept is reduced (Hewson, 1982), and this can only occur when the student having an existing concept has enough reason to be dissatisfied with it. Treagust et al. (2008) further explained that the new concept may be assimilated together with the previous one if a competing concept fails to generate dissatisfaction. Also, they noticed that if dissatisfaction occurring between competing concepts are not compatible, two or more conceptual events may take place, and if the new concept attains a higher status than the preexisting one, accommodation (conceptual change) can occur. However conceptual exchange cannot occur if the old concept retains a higher status than the new concept learnt. Therefore Hewson (1982) stressed that a replaced concept is not forgotten since the student may wholly or partially reinstate it at a later time. Consequently, both Posner et al., (1982) and Hewson (1982) emphasized that it is the student who makes the decisions regarding conceptual status and conceptual changes and not the teacher.

Implications of Conceptual Change Theories in Teaching and Learning

The discussion of conceptual change theories and models resulted in the question, how could teachers create an enabling environment that will be easy for enhancing conceptual change in students? This question has excited many researchers to investigate teaching and learning approaches that have the capacity for improving teaching practices and have high efficacy for remediating conceptual change. The theoretical perspectives have also provided the framework for designing effective teaching and learning strategies which are considered superior to the existing conventional instructional designs (Chen & Wang, 2016). The aim of teaching is not to compel students to ignore their existing concepts and accept the new one presented by the teacher, but instead, to assist students cultivate the attitude of challenging one's existing idea with another and develop proper strategies for getting existing concepts compete with one another for acceptance (Zembylas, 2005). Consequently, conceptual change is very important in science education at least in two major aspects, namely, learning of science and teaching of science.

Learning of science

As already indicated, studies have revealed that students hold diverse forms of misconceptions regarding science concepts and misconceptions about the world around them. These misconceptions vary greatly according to aspects including clarity, coherence and ambiguity. This presupposes that the learning of new concepts by students is largely affected by their existing knowledge in ways that may hinder or assist their learning processes. Accordingly, it is important to view the learning of the preferred result as a process of conceptual change.

Teaching science

It has already been established from literature that students in the classroom hold diverse forms of misconceptions. Therefore, the role of the teacher is to responsibly engage in teaching strategies that evokes student's misconceptions and develop better ways of helping them arrive at conceptual change. Although some researchers contend for responsibilities to be separated between teachers introducing the content and the students learning it. Svandova (2008) posited that the duty of the teacher is mainly to become aware of the misconception's students bring to the classroom and strategize the means to help students arrive at conceptual change.

Important Teaching Strategies Based on Conceptual Change Process.

Research has shown that various processes are involved in learning of which conceptual change forms a key aspect. Several studies have shown that the conventional teaching method is not successful in facilitating conceptual change (Nas, 2010) because Conventional teaching is regarded as merely introducing new information to students without necessarily considering the existing misconceptions students bring to the classroom. As pointed out by Quainoo et al. (2021), "quality of instruction is always due to a certain orchestration of various instructional methods and strategies that targets students' misconceptions"(page 19). Hence, conceptual change teaching strategies have received a wide attention over the past decades in science education. Numerous researches in science education in recent years have targeted students' misconceptions of natural phenomena such as photosynthesis.

A number of different features have emerged as characteristic components of conceptual change teaching from these studies. One major important component of conceptual change teaching is diagnostic stage which is essential for determining the existing students' misconceptions that could hinder the learning process (Ray & Beardsley, 2008). It has been established that teaching that has included elicitation or diagnosis of students' misconceptions has been successful in helping basic and SHS students improve significantly in their understanding of biological concepts (Armagan et al., 2017).

The responsibility of the teacher in conceptual change teaching strategy is to create conducive atmosphere so that every student cab express himself or herself without any fear of embarrassment, and to seek to it that students are the main determiner of what they perceive as a correct concept in the classroom (Nkechinyere & Arokoyu, 2018). Therefore, students are to be responsible for their own learning and to accept others' conceptions, and to alter their conceptions if others seems more intelligible and plausible. In light of this, one major responsibility of every students is to monitor his or her own learning processes.

Nadelson (2018) opined that decisions involved in teaching should be considered at three levels in the planning of conceptual change lesson. First of all, teachers have to create a serene learning environment suitable for supporting conceptual change through the provision of opportunities for classroom discussion and consideration of alternative viewpoints and arguments. The choice of teaching strategies is also another important level of decision-making in planning effective conceptual change lesson. Lastly, the teacher must also consider the choice of specific learning tasks that address the demand of the particular science domain.

Four factors are necessary to be considered during the selection of specific teaching strategies including: previous conceptions and attitudes of students, the nature of intended learning outcomes, the cognitive stage or intellectual capacity of the student and the teaching strategy involved (Tuera, 2019). Two distinct groups of strategies are noted to promote conceptual change from the standpoint of possible teaching. The first group focuses on cognitive conflict and resolution of conflicting perspectives. The second group of strategy is based on Piaget's theory of concept learning which is built upon the Piagetian notion of accommodation (Ozdemir).

Although many studies in science education have highlighted on various conceptual change strategies they view as effective in remediating students' misconceptions including the concept attainment model, generative learning model, copious studies have revealed that Concept cartoons and Conceptual change texts teaching strategies are useful in dealing with students' misconception of abstract concepts in science including photosynthesis.

Conceptual Change Texts (CCTs)

According to science literature, one of the notably and widely accepted conceptual change teaching strategies is conceptual change texts. Several studies on the use of conceptual change texts in facilitating understanding of students have been conducted in science education. (Alkhawaldeh & Salem, 2019; Cepni & Emine, 2010; Ozmen, 2007). According to Cakir, Geban and Yuruk, (2002), it is considered as an effective tool which can be used to make conceptual changes permanently in students' existing conceptions. conceptual change texts are useful in activating students' preexisting conceptions, introducing students to frequent misconceptions and help students understand scientifically accepted explanations (Armagan et al., 2017). Conceptual change texts as pointed out by Abdulkadir (2018) are texts which bring about transformation of inaccurate students' knowledge on a particular science concept. In all subject areas, it has been noted to be helpful in remediating conceptual mistakes (Cepni & Emine, 2010). They are intentionally planned at changing students' misconceptions and focus on instructional strategies that improve conceptual change where the students' preexisting conceptions are challenged, producing dissatisfaction and then followed by the accurate concept which is both intelligible and fruitful (Ozmen, 2007). The common and most frequent occurring misconceptions of students are first revealed by these texts in the initial stage by exposing them with situations with the intention to bring out the misconceptions they hold followed by the proof that these misconceptions are incorrect. Afterwards, they are presented with the explanations supported by examples which are fruitful, intelligible and plausible (Cepni & Emine, 2010).

A meta-analysis studies was conducted by Armagan et al., (2017) on the effectiveness of conceptual change texts (CCT) on academic achievement where they examined 42 published and unpublished studies. Their study revealed that Conceptual change texts was effective in promoting students' conceptual understanding. Following their research, the following suggestions were made regarding science education and curriculum development: The curriculum developers should suggest the usage of conceptual change texts in leaning science particularly biology; in-service training courses regarding Conceptual change texts should be arranged for the science teachers. Also, a course about Conceptual change texts should be mounted for every teacher in the education sector; Textbook writers and textbook evaluation committee should pay attention to conceptual change teaching in order to deal with misconceptions of students; Studies on conceptual change texts should be considered as priority by Ministry of Education and the Scientific and Technological Research Council (Armagan et al., 2017). In view of this, it is important for the Ministry of Education to reconsider the utilization of Conceptual change texts in teaching Biology in the Senior High Schools in Ghana.

A comparative study on conceptual change was conducted by Alkhawaldeh and Salem (2019) where they determined the effects of cyclic inquiry model, conceptual change cext, and conventional instruction on Students' understanding of photosynthesis and respiration in plants. In this study, they taught 33 students with the cyclic inquiry model, 34 students with the conceptual change texts (CCT), and 34 students with the conventional instruction (TI). The results from their studies revealed that students in the experimental groups involving cyclic inquiry model and conceptual change texts outperformed their counterparts in the conventional group supporting the claim that conceptual change texts is effective teaching strategy which can be used to bring about a conceptual change.

Similarly, Balci et al. (2006) investigated the effects of the Engagement, Exploration, Explanation, Extension, and Evaluation (5E) learning cycle, Conceptual change texts, and Conventional instructions on 8th grade students' understanding of photosynthesis and respiration in plants where the 5E learning cycle strategy was used to teach those in the first experimental whiles those in the second experimental group were taught using the conceptual change text, and finally students in the control group were taught using the conventional approach. Their results revealed significant improvement in the performance of students in the experimental groups compared to those in the conventional group. This suggests that the conceptual change text is as equally effective as the 5E learning model (Balci et al., 2006).

Concept Cartoons

Concept cartoons is another effective technique used in remedying student's misconceptions and facilitating conceptual change of abstract concepts such as photosynthesis (Akamca et al., 2009; Gafoor & Shilna, 2013). In science education, it has been employed in a number of ways such as problem solving and thinking skills, resolving conflict, promoting motivation and making scientific ideas accessible (Gafoor & Shilna, 2013). It is strongly believed by researchers that ideas presented through cartoons are easy to understand through the action of the cartoon characters. Therefore, concept cartoons are very good teaching approach in bringing about conceptual change. In spite of the attempt by researchers in promoting its use in the classroom, it is however worrisome to note that, it is still one of the teaching approaches which has received very little attention in the classroom particularly in Senior High Schools in Ghana.

Concept cartoons are interesting and exciting drawings in the form of cartoons comprising three or more individuals suggesting ideas, making discussions concerning a particular concept whereby each cartoon character defends different viewpoints concerning a particular concept (Keogh & Naylor, 1999). This was introduced in an attempt to bring about interesting activities that could help facilitate learning and understanding of abstract concepts in science and to ensure that students participate significantly in class (Akamca et al., 2009). concept cartoons were first developed in the 1990s by Keogh and Naylor in an attempt to enlighten the relationship between constructivist approach and epistemology and classroom applications. The motive that necessitated its introduction was to basically bring about a teaching and learning strategy that could best help in identifying students´ misconceptions with the help of exciting drawings (Akamca et al., 2013).

Generally, it is believed that majority of individuals visually take in about 75-80% of information. Therefore, because concept cartoons combine visual elements with texts in the form of argument, it easily facilitates information processing in students. This is because, when cartoons are combined with text, it becomes easier for students to understand even abstract scientific concepts which otherwise would have been difficult to understand through conventional instruction (Ezra *et al.*, 2013). A notable characteristic about concept cartoons is that among the other ideas proposed by the cartoon characters in the drawing, only one of them may be scientifically acceptable whiles other incorrect scientific ideas are based on students' intuitions and experiences (Stephenson &Warwick, 2002).

Concept cartoons have several advantages over other teaching approaches. One of such advantages is that, it has the capacity to grab students' attention and generate class participation and also has the tendency to engage students in focused discussion. This is because students are challenged and motivated to participate in the discussions presented by the cartoon characters. It has been observed that both children and adults like cartoons (Stephenson & Warwick, 2002) because of the connection between cartoons, fun and humour. It has been reported that concept cartoons provide funny and interesting ways to represent new concepts to students, and because of the funny nature of cartoons, students seem to be more motivated and eager towards the activity, and are more likely to be focus and receptive towards the learning (Keogh & Naylor, 1991). Concerning generation of attention, Gafoor and Shilna (2013) proposed that ideas in cartoons can be thought provoking to the extent that students are easily captivated into participating in the discussion by becoming one of the cartoon characters. Consequently, the lesson becomes more interactive and student-centered because all students get involved in the teaching and learning process. Akamca et al. (2009) also observed that concept cartoon has the inherent ability to elicit and eliminate students' misconceptions, bring about argument in the learning process and serves as an effective stimulus for a form of argumentation in learning scientific concepts. More so, Keogh and Naylor (1999) emphasized that the process of argumentation is very necessary as a way of leading students to engage in scientific enquiry, investigation and resolving argument. Perales and Vilchez (2005) also identified that concept cartoon strategy forms the basis for effective practical work, and help reduces mismanagement in the classroom due to the exciting discussions that help engage all students to participate in the classroom discussion.

Gafoor *a*nd Shilna (2013) suggested various ways of using concept cartoons in science courses. They indicated it may be used as a method of teaching or as an instructional material. Thus, concept cartoons related to particular scientific concepts such as photosynthesis can be prepared as an instructional material in the form of worksheet in advance which can be used in making teaching and learning easier. Ekici et al., (2007) suggested that concept cartoons worksheet for teaching in the classroom should be made up of few texts in order to be appealing to students. They further proposed that the different ideas presented by the cartoon characters should draw on research which diagnoses common misconceptions among students so that all the other alternatives may likely appear credible to them. Additionally, Keogh, Naylor and Wilson, (1998) maintained that the alternatives presented by the cartoon characters should all be of equal status or level of difficulty so that learners cannot easily from the context figure out the correct alternative.

Akamca et al., (2013) explored the effect of computer aided concept cartoons on student's achievement in science and technology education using 4th grade science and technology. Results of their study indicated that concept cartoons strategy have positive impact on students' achievement in classification of living things. Esra (2013) also studied the effects of cartoons on students' achievement and attitudes in biology using 56 SHS students. The results of the study revealed that students' knowledge, understanding and attitude of biology had improved significantly in the concept cartoons group (Ezra, 2013). Concerning studies on photosynthesis, Ekici et al. (2007) investigated the effect of concept cartoons in diagnosing and overcoming students' misconceptions related to Photosynthesis in Turkey. The results from the study revealed that concept cartoons was effective not only in identifying student misconceptions but also a better approach for overcoming students' misconceptions in photosynthesis (Ekici et al., 2007).

From the foregoing, it has been established by literature that students show difficulty in understanding photosynthesis due to the various misconceptions associated with the concept. Although several researchers in science education have developed various teaching approaches in an attempt to address this problem confronting students particularly in SHS. In spite of this, student's difficulty in science concept particularly photosynthesis still persists blaming on the fact that most of the approaches used by teachers do not directly address students' misconceptions. Numerous studies in science education have revealed that conceptual change instructional strategies are the most effective way in facilitating conceptual change in students because they directly address students' misconceptions which is a major barrier to students' conceptual understanding.

Previous studies have sought to investigate the effect of some conceptual change instructional approaches on SHS students' conceptual understanding of difficult biology concepts in Ghana. However, very little attention has been given to concept cartoons and conceptual change texts resulting in scanty literature on these instructional approaches. Additionally, these studies focused only on their effectiveness without actually measuring the extent to which students' knowledge had improved. More so, they failed to diagnose and explore students' misconceptions in difficult biology concepts like photosynthesis. In view of this, this study sought to determine the effect of Concept cartoons and Conceptual change texts in improving SHS students' understanding in Photosynthesis.

The Impact of Concept Cartoons on Students' Achievement in Photosynthesis: High versus Low Achievers.

Concept cartoons are visual tools that present everyday scenarios with multiple viewpoints on a scientific concept. These viewpoints often include common misconceptions alongside the correct scientific explanation, encouraging students to engage in critical thinking and discussion. By providing a concrete and relatable context, concept cartoons can help students visualize and understand abstract scientific ideas, such as the process of photosynthesis (Keogh & Naylor, 1999). High achievers, who typically possess strong cognitive skills and prior knowledge, benefit from the interactive and discussion-based nature of concept cartoons. These students are often more engaged by tasks that require higher-order thinking, such as evaluating different viewpoints and defending their reasoning. For high achievers, concept cartoons serve as a platform to deepen their understanding and explore the nuances of scientific concepts. Studies have shown that high achievers excel in environments that promote critical thinking and discussion, which are key elements in the use of concept cartoons (Morrison et al., 2008).

For low achievers, who may struggle with abstract concepts and have weaker foundational knowledge, concept cartoons provide a scaffolded learning experience. The visual and contextual nature of concept cartoons helps make complex ideas more accessible and less intimidating. By breaking down the concept of photosynthesis into relatable scenarios, concept cartoons can reduce cognitive load and help low achievers connect new information to their existing knowledge (Keogh & Naylor, 2007). However, low achievers might require additional support, such as guided questioning or teacher intervention, to fully benefit from this tool.

Comparative studies on achievement levels

Research comparing the impact of concept cartoons on high and low achievers has revealed that while both groups show improvement, the nature of their gains can differ. High achievers often exhibit significant increases in their ability to apply concepts to novel situations, while low achievers tend to show improvement in their basic understanding and retention of the material (Kabapinar, 2005). These findings suggest that concept cartoons can be a versatile tool, benefiting students across the achievement spectrum, though the depth and nature of their learning may vary.

The Impact of Conceptual Change Texts on Students' Achievement in Photosynthesis: High versus Low Achievers.

Conceptual change texts are carefully crafted instructional materials designed to directly address and correct students' misconceptions. These texts typically include a refutation of common misconceptions followed by a scientifically accurate explanation, helping students to restructure their existing knowledge frameworks. In the context of photosynthesis, conceptual change texts can clarify misunderstandings about complex processes like energy transformation and the role of chlorophyll (Guzzetti et al., 1993).

High achievers, who are generally adept at reading comprehension and critical analysis, are well-positioned to benefit from conceptual change texts. These students are likely to appreciate the logical structure and clarity of the texts, which help them refine their understanding and connect new information with their prior knowledge. For high achievers, conceptual change texts can facilitate deeper learning by challenging them to reconsider their existing ideas and integrate more sophisticated scientific concepts (Mason, 2001). Studies have found that high achievers often show marked improvements in their conceptual understanding and are better able to apply scientific principles to complex scenarios after engaging with these texts.

For low achievers, the effectiveness of conceptual change texts can depend on the design and presentation of the material. If the texts are too dense or complex, low achievers may struggle to process the information, leading to minimal gains in understanding. However, when the texts are designed with clear, straightforward language and include supportive elements such as diagrams or simplified explanations, they can be highly effective in addressing misconceptions and enhancing comprehension (Diakidoy et al., 2003). Research has shown that low achievers can make significant progress in their understanding of photosynthesis when conceptual change texts are tailored to their reading level and cognitive abilities.

Comparative studies on achievement levels

Studies comparing the effects of conceptual change texts on high and low achievers indicate that while both groups benefit, the degree and nature of their gains differ. High achievers tend to show improvements in their ability to engage with and critically analyze scientific texts, leading to a deeper and more nuanced understanding of the content. Low achievers, on the other hand, often show gains in their basic conceptual understanding and are better able to correct specific misconceptions when provided with clear, accessible texts (Mikkila-Erdmann, 2001).

The literature suggests that both concept cartoons and conceptual change texts are effective tools for improving students' understanding of photosynthesis, though their impact varies between high and low achievers. High achievers benefit from the opportunities for critical thinking and deeper engagement provided by these tools, leading to more sophisticated conceptual understanding. Low achievers, while also benefiting from these instructional strategies, may require additional support and carefully designed materials to achieve significant learning gains. Ultimately, the successful implementation of these tools depends on understanding the specific needs of different achievement levels and adapting instructional strategies accordingly.

Perceptions of Concept cartoons in the Classroom: A Student Perspective.

Student perceptions are a crucial factor in the effectiveness of educational interventions. How students perceive a teaching tool can significantly influence their engagement, motivation, and ultimately their learning outcomes. In science education, particularly in challenging topics like photosynthesis, students' attitudes toward and acceptance of instructional tools can determine whether these tools succeed in facilitating conceptual change (Osborne et al., 2003). Understanding these perceptions helps educators tailor their teaching strategies to better meet students' needs and promote more effective learning.

Students generally respond positively to concept cartoons, particularly because of their visual and interactive nature. Research has shown that students find concept cartoons to be engaging and enjoyable, which increases their willingness to participate in discussions and explore different ideas (Morrison et al., 2008). The informal and non-threatening presentation of scientific ideas in concept cartoons allows students to express their thoughts more freely, fostering a classroom environment conducive to learning.

However, student perceptions can vary depending on their academic achievement levels. High achievers may appreciate the challenge that concept cartoons present, enjoying the opportunity to debate and defend their ideas. These students often view concept cartoons as a way to deepen their understanding and refine their knowledge through critical analysis (Keogh & Naylor, 2007). On the other hand, low achievers might initially feel intimidated by the need to articulate their thoughts in front of peers, but they often come to appreciate the clarity and context that concept cartoons provide, which helps them grasp difficult concepts more effectively (Kabapinar, 2005).

The positive perceptions of concept cartoons correlate with improved learning outcomes, particularly in complex topics like photosynthesis. When students are engaged and motivated, they are more likely to participate actively in the learning process, leading to better retention and understanding of the material (Naylor & Keogh, 2013). The visual and narrative elements of concept cartoons help demystify the abstract processes involved in photosynthesis, making the concept more relatable and easier to understand.

Perceptions of Conceptual change texts in the Classroom: A Student Perspective.

Students' perceptions of conceptual change texts tend to vary based on their reading abilities and prior knowledge. High achievers, who typically have stronger reading comprehension skills, often find conceptual change texts to be a valuable resource that helps them consolidate and expand their understanding of scientific concepts (Mason, 2001). They appreciate the logical structure and clarity of the texts, which guide them through complex explanations in a systematic way.

Low achievers, however, may perceive conceptual change texts as challenging, especially if the language is dense or the content is not sufficiently scaffolded. These students might struggle with the refutational format, which requires them to critically evaluate their existing beliefs and accept new information (Diakidoy et al., 2003). Despite these challenges, when conceptual change texts are carefully designed with clear language and supportive visuals, even low achievers can find them helpful in overcoming misconceptions and improving their understanding.

Comparative perceptions and combined impact of Concept cartoons and Conceptual change texts.

When comparing student perceptions of concept cartoons and conceptual change texts, several key differences emerge. Concept cartoons are generally perceived as more engaging and enjoyable, particularly because of their visual and interactive nature. Students are more likely to view concept cartoons as a fun and less intimidating way to learn complex scientific concepts (Keogh & Naylor, 2007). On the other hand, conceptual change texts, while effective, may be perceived as more challenging, especially by students who struggle with reading comprehension. However, the effectiveness of each tool is enhanced when used in combination. Concept cartoons can stimulate interest and discussion, providing a gateway for deeper exploration of the concepts. Following this, conceptual change texts can offer the detailed explanations needed to solidify understanding and correct any lingering misconceptions. This combined approach can cater to different learning styles and abilities, making the learning experience more comprehensive and effective (Naylor & Keogh, 2013).

Students generally perceive the combined use of concept cartoons and conceptual change texts positively, particularly when the materials are integrated in a way that builds on their strengths. High achievers appreciate the opportunity to engage with both visual and textual representations of scientific concepts, which allows them to approach learning from multiple angles (Morrison et al., 2008). Low achievers, while initially finding the texts challenging, often benefit from the structured guidance provided by the conceptual change texts after being introduced to the concepts through cartoons. This complementary use of concept cartoons and conceptual change texts can create a more dynamic and supportive learning environment, where students feel encouraged to explore and understand complex ideas like photosynthesis. By addressing both the affective and cognitive needs of students, this approach helps to foster a more inclusive and effective science education experience.

Student perceptions play a significant role in the effectiveness of instructional tools like concept cartoons and conceptual change texts in enhancing the understanding of photosynthesis. While each tool has its strengths and potential challenges, their combined use can cater to the diverse needs of students, making learning more engaging and effective. concept cartoons are generally perceived as more engaging and less intimidating, particularly for low achievers, while conceptual change texts provide the detailed explanations needed for deep learning, especially for high achievers. By understanding and addressing student perceptions, educators can optimize the use of these tools to improve conceptual understanding in science education.

CHAPTER THREE

RESEARCH METHODS

Overview

This chapter discusses the research design, the study area, the population for study, the sample and sampling procedures, data collection instruments used and the data collection procedures and data processing and analysis.

Research Philosophy

This study is grounded in the philosophy of pragmatism, which prioritizes practical solutions and the use of methods that are most effective for answering the research questions. Pragmatism is well-suited to this research because it allows for the integration of both quantitative and qualitative methods to provide a comprehensive understanding of how concept cartoons and conceptual change texts impact students' understanding of photosynthesis. Pragmatism supports the idea that research should focus on the outcomes and the usefulness of findings in real-world contexts. By adopting this philosophy, the study emphasizes the practical application of different instructional strategies and their effectiveness in enhancing students' conceptual understanding, providing insights that can be directly applied in educational settings.

Research Approach

This study followed the Embedded Mixed-Methods research approach. This study combines both quantitative and qualitative research methods within a single study, with the quantitative method being the primary focus, while the qualitative was used to provide supplementary insights. Thus, the qualitative data was embedded within the predominantly quantitative study to enrich and contextualize the findings (Creswell & Clark, 2012). Initially, a pre-test was conducted to establish a baseline of students' conceptual understanding. This was followed by gathering qualitative data to gain insights into their misconceptions and initial thoughts. After the intervention, a post-test was administered to quantitatively measure any improvement in understanding. Following the post-test, another set of interviews was conducted to capture qualitative data on the students' experiences and the nature of any conceptual changes. This design allowed for a comprehensive analysis, with the quantitative data providing measurable evidence of change, and the qualitative data offering deeper insight into the students' learning process. (Hanson, Creswell, Clark, Petska & Cresswell, 2005).

This design is illustrated as below:

	Pre-test	**Intervention**	**Post-test**
EGA	T	X1	T
EGB	T	X2	T
CG	T	XO	T

Table 1: *Pre-test-post-test quasi experimental method* (Ozmen, 2007).

EGA represents participants in conceptual change texts group(X1), EGB represents participants in concept cartoons group (X2) and CG represents participants in the control group (XO). T represents the Photosynthesis Achievement tests (PAT). The broken line separating the three groups indicates that participants were not randomly assigned to the treatment groups (Ozmen, 2007).

Research Design

The research design is a quasi-experimental design with a pre-test/post-test structure. This design is chosen to evaluate the impact of different instructional strategies—concept cartoons, conceptual change texts, and conventional methods—on students' understanding of photosynthesis.

Students are assessed before and after the instructional interventions using pre-tests and post-tests. This design helps measure the change in students' understanding and identifies any statistically significant differences between the groups taught with different methods. The combination of this designs within the mixed method approach allows the study to robustly address the research questions, providing both numerical data on student performance and qualitative insights into their learning experiences.

Population

All Form 3 SHS students who offered the General Science programme and read Elective Biology in Jomoro and Ellembele Educational District formed the target population of this study. Three hundred and fifty (350) students formed the population of the study.

Sampling Procedure

A Multi-stage sampling approach was employed to obtain participants for the study (Cohen, Manion & Morrison, 2007). Multi-stage sampling is a sampling technique which contains two or more stages in sample selection. This approach was used for this study because it allows large collection of population to be put into smaller groups in several stages to facilitate easy collection and management of primary data (Cohen, Manion & Morrison, 2017). Seven schools in Jomoro and Ellembele Educational District were selected for the study. Five schools out of the seven were purposively sampled because they had treated photosynthesis. Schools where students had prior knowledge in photosynthesis were selected to ensure that participants have a foundational understanding of photosynthesis, allowing the researcher to assess the impact of the teaching intervention on improving and refining existing knowledge, rather than on teaching the concept from the scratch. This approach allows for a precise evaluation of how well the intervention addresses the initial misconceptions identified and help improves understanding among students who already have prior knowledge of photosynthesis. Without prior instructions, it would be challenging to identify and address specific misconceptions related to photosynthesis. This might not measure how well the intervention corrects misconceptions if these misconceptions have not yet been identified through previous instruction. The remaining two schools had not yet treated photosynthesis hence were not considered for this study. Three schools out of the five were randomly sampled through computer generated random numbers. This was done to give each school an equal chance of being selected. In schools where there were more than two streams of classes that offered biology, a simple random sampling technique was used to select one. Those that had only one biology class had it automatically selected. The three schools were randomly assigned as treatment and control groups. Hundred and thirteen (113) students were sampled for the study. School A consisted of 33 students (24 males and 9 females). Participants from School B consisted of 42 students (20 males and 22 females) whiles 38 participants were used in school C (23 males and 15 females). Six (6) students from the concept cartoons and conceptual change texts groups were purposively selected for interview. Students in each study groups were categorized into three performance groups (low-performing, average performing and high performing). From each performance group, two students were selected. This approach aimed to ensure that interviews included perspectives from different levels of understanding and performance. To achieve balance representation, both male and female were included in each performance group. This stratification aimed to provide a comprehensive view of how the intervention impacted students of different genders within each performance level. The mean age of the students was 18 and a standard deviation of 0.09.

Data Collection Instruments

Two types of instruments were used in this study: Photosynthesis Achievement test (PAT) and a semi structured interview guide. Photosynthesis Achievement test (PAT) was prepared by the researcher following the well-established steps provided by Haslam and Treagust (1987), who are well-recognized in the field of science education for their work on diagnostic testing and conceptual understanding. Their approach to two tier testing is well established, providing a strong foundation for the credibility of the test items.

The semi structured interview guide was also designed by the researcher following the well-established laid down steps by Driver, Guesne and Tiberghien (1985), who are prominent figures in science education, known for their extensive work on students' conceptual understanding in science. They are well advocated for the use of interviews to explore students' ideas and the effectiveness of instructional strategies. The instruments were designed to gain understanding into Senior High School students' conceptual understanding of concepts related to photosynthesis. The tests items covered all aspects of photosynthesis as outlined in the Elective Biology syllabus for Ghanaian Senior High School. The two-tier multiple test (PAT) consisted of 25 items and each item had four alternatives. The alternatives had one correct answer and three distracters that reflected students' probable misconceptions reported in the related literature. The two-tier multiple-choice test was used because it had proven to be very reliable and valid for assessing students' conceptual understanding of difficult concepts in biology (Haslam & Treagust, 1987). The first tier of each item corresponded to content based on propositional knowledge statement. The second tier consisted of reasons based on students' responses. These reasons included identified misconceptions and a scientifically acceptable answer.

Students' improvement in understanding (knowledge gain) in concepts related to photosynthesis from the intervention was measured by subtracting the percentage of correct answers (out of 50) that they scored on the pre-test from the percentage of correct scores on the post-test. Positive values indicated an increase in students' knowledge (improvement) in concepts related to photosynthesis at the end of the intervention whiles zero or negative values denoted no improvement (knowledge gain). The higher the percentage value, the more knowledge gained by students at the end of the study (Delucchi, 2014).

Item difficulty and the discrimination indices of the items used to gather data were also determined. The item difficulty index for each test item was determined by dividing the number of students who chose the correct answer by the total number of students. If item difficulty index was more than 0.75, it was considered easy and was carefully analysed and deleted. Item difficulty index which was below 0.25 was considered too difficult and was deleted. Items which had difficulty index between 0.25-0.75 were considered appropriate (Kocdar, Karadag &Murat, 2016).

The item discrimination index (D) was determined for each item through the following steps: The students' scripts were arranged with the highest overall scores at the top. The students' scripts were divided into upper and lower groups. The number of students in the upper and lower groups who had each item correct were counted. The number of students in the lower group who got the item correct was subtracted from the number of students in the upper group who had the item correct. The value obtained was divided by the number of students in each group to obtain the item discrimination index (D) (Kocdar, Karadag &Murat, 2016).

The semi structured interview guide consisted of three open ended questions developed by the researcher to gain deeper insight into students' view on the use of conceptual change texts and concepts cartoons in teaching and learning of Biology. The open-ended questions that were asked participants in the Concept cartoons group were as follow: (1) what is your view about using

Concept cartoons in teaching biology? Please explain your response (2) how did the Concept cartoons affect your learning of photosynthesis? Please explain your response (3) would you recommend concept cartoons as an alternative teaching approach in Senior High Schools? Please explain your **r**esponse**.** The open-ended questions that were asked participants in the conceptual change texts group were as follow: (1) what is your view about using conceptual change texts in teaching biology? Please explain your response (2) how did the Conceptual change texts affect your learning of photosynthesis? Please explain your response (3) would you recommend conceptual change texts as an alternative teaching approach in Senior High Schools? Please explain your response.

Students' responses to the open-ended question were grouped and analysed by descriptive analysis (Taslidere, 2021). Findings of related concepts that were repeated were brought together as an idea. Generally, five ideas emerged from the responses comprising positive effect, improvement of understanding; motivation, class participation and interesting/funny.

The lesson plans developed for the concept cartoons and conceptual change texts were presented to experts in biology education at the Department of Science Education of the University of Cape Coast for review.

Validity of instrument

Construct validity was maintained by following the steps used by Haslam and Treagust in developing two-tier diagnostic tests. The first tier assesses the factual knowledge, while the second tier probes the reasoning behind the choice, ensuring the test measures students' understanding of photosynthesis, not just rote memorization. For the validity of research instruments and to ensure that participants' scores from the test were valid, the test instruments were initially presented to five senior biology teachers in the municipality for their review before it was presented for final review by expert in Biology education for comments and suggestions. Expert opinion was sought regarding the open-ended questions used in the interview guide to make ensure the content was valid.

Pilot testing of instruments

A pilot-test using 43 Form 3 Elective Biology students in a SHS outside the district of those used for the main study was conducted. Following the pilot-testing, modifications of the test items' construction were made. Data from the pilot test were statistically analysed to determine the reliability of the test instruments using the Kuder Richardson formula (KR-21). The KR-21 was used because the items were dichotomously scored (either a student had it correct or wrong). The reliability for the test was found to be 0.73. This level of reliability coefficient obtained according to Ozmen (2007), indicated that the test could be considered satisfactorily reliable. A correct answer was given one point for the multiple choice and a correct explanation to the answer also scored one point which made the maximum possible score from the test 50 points.

Data Collection Procedures

The data collection procedure was divided into three phases; pre-treatment phase, treatment phase and post-treatment phase. To place the research in context of this design, three SHS schools were selected and placed into three (3) groups A, B and C respectively. From the outcome of the simple random sampling, Participants in group A constituted the conceptual change texts group (EGA). Participants in group B constituted the concept cartoons (EGB) group whereas participants in C formed the conventional approach group (CC). The participants in each group were initially pre-tested using two tier multiple test developed by the researcher labelled photosynthesis Achievement test one (PAT-1). Post-test was conducted one week after the intervention using the same two-tier multiple test but labelled as photosynthesis Achievement test two (PAT-2).

Pre-treatment phase

During this phase, the researcher met and established rapport with the students and introduced himself to the students. The purpose for the study was also explained to the students. After the interaction, the pre-test instrument (PAT-1) on concepts in photosynthesis was administered to EGA, EGB and control group (CG). Before the test, guidelines concerning the test were explained to the students and any misunderstandings concerning the test were clarified before it was administered. It was ensured students did interact. The test lasted for one hour after which the papers were collected.

The treatment phase:

The treatment phase involved the administration of the teaching interventions (conceptual change text, concept cartoons and the conventional approach).

(a) Administration of Conceptual change texts.

Literature was thoroughly surveyed in order to list areas in photosynthesis that students have misconceptions and difficulty. Also, the lesson objectives outlined by the Ghanaian Elective Biology syllabus was surveyed to identify and cover the essential areas of photosynthesis. Lessons on conceptual change texts were prepared in accordance with the steps outlined by Cepni and Emine (2010) whiles taking into consideration the four conditions necessary for Conceptual change to occur proposed by Keogh and Naylor (1999). Seven weeks were used to complete the entire lesson which consisted of five (7) sections. Conceptual change texts were photocopied and given to students. Each copy was divided into five sections.

In the first section, students were asked a question on a particular concept, and were asked to write their answers in the given blank spaces in the sheets provided. The students were asked to work with the conceptual change texts individually during this section. After all the students have written their answers, the researcher asked the students to volunteer and share their answers with the class. The students' answers given in this section revealed their misconceptions. After this, the researcher distributed the second sections of the conceptual change texts to the students which contained common misconceptions students had regarding photosynthesis and the reasons for the misconceptions. Thus, this section consisted of a table that showed common misconceptions on one column and another column showing the reasons of these misconceptions formed by students. The wrong ideas and their reasons were read by the students and the reasoning why the concepts were wrong was emphasized by the teacher. The fourth section which contained the right ideas and their reasons were also given to students to read and were emphasized by the teacher. This section caused the students to be dissatisfied with their pre-existing ideas.

Reading texts in this section (section 4) including examples, activities and demonstrations which were intelligible, plausible and fruitful were given to students to prove the correct concepts so that students abandoned their pre-existing conceptions and accepted the new concept. After this, questions about the particular concept taught were given to students to attempt individually, after which were collected, marked and given back to the students.

(b) Administration of Concept cartoons.

Literature were thoroughly surveyed in order to identify common misconceptions that are associated with photosynthesis among Senior High School students. Considering the objectives outlined in the elective biology syllabus, the researcher designed concept cartoons lesson about photosynthesis taking into consideration the criteria outlined by Keogh and Naylor (1999). Therefore, the following concept cartoons were prepared to reflect students' misconceptions: the process of photosynthesis, the adaptation of leaf for photosynthesis, the fate of the product of photosynthesis and the biochemical nature of photosynthesis.

The concept cartoons were given to the students in EGB. The students were made to observe, read carefully and work on the questions individually. When they finished, the students were put into groups of six (6) and were encouraged to discuss, compare answers and argue about their responses to the scientific questions and problems presented through the cartoons. After the group discussions, one person from each group was called to present their answers whiles other students paid attention and participated by asking questions and taking notes. After the group presentation, the teacher acting as a facilitator had a whole class discussion with students by paying detailed attention to the areas where the students had misconceptions and encountered difficulties during the previous sections. During this section, with examples, activities, demonstrations/experiment, teacher provided scientifically accepted concept that were intelligible, plausible and fruitful (Ozdemir & Clark, 2008) to students. After this, questions about the particular concept taught were given to students to attempt individually, after which they were collected, marked and given back to the students.

The lesson was completed by the same researcher within seven weeks (one-hour lecture per week). The two experimental groups spent an equal time studying the same concept and all the objectives outlined for the topic was covered in both experimental groups. All aspects of photosynthesis outlines in the Elective Biology syllabus was thoroughly covered. These aspects of photosynthesis covered included: the process of photosynthesis, structural adaptation of the leaf for photosynthesis, fate of the product of photosynthesis, conditions necessary for photosynthesis, products of photosynthesis, factors affecting the rate of photosynthesis and the biochemical nature of photosynthesis.

(c) Administration of conventional teaching approach.

The Elective Biology curriculum for Senior High Schools was consulted to identify and cover the essential areas of photosynthesis. Seven weeks lessons based on the conventional teaching approach specified in the curriculum was prepared. The lesson plan included introduction, content development, main ideas, application, closure and assignment. Seven weeks were used to complete the entire lesson which consisted of five (5) sections.

Post-treatment phase

In order to explore students' misconceptions on concepts related to photosynthesis and to determine the extent of improvement in their understanding due to the intervention (concept cartoons and conceptual change texts strategy), Post-test (PAT-2) was administered to all groups one week after the intervention. After this, individual interview was conducted based on their school performance as recorded by their class teacher. Thus, two above average, three average and two below average students consisting of one boy and one girl were selected from each concept cartoons and the conceptual change texts groups. Their responses were recorded and coded thematically.

Lesson plans used for the study:

Below is sample lesson plan (week one only) used in this study.

Conventional lesson plan week 1

Topic: Photosynthesis

Subtopic: Introduction to photosynthesis

Duration: 60 minutes

Specific objectives: By the end of the lesson the student will be able to:

1. Define photosynthesis
2. Describe briefly the process of photosynthesis
3. State four importance of photosynthesis
4. Write a balanced chemical equation for photosynthesis

Relevant previous knowledge: Students have learnt about plant nutrition in integrated science therefore; they will be able to mention some of the things required by plants for photosynthesis.

Teaching/Learning materials: Chat and marker board illustrations.

Introduction (5 minutes)

Teacher activity: Teacher uses questions to review students' relevant previous knowledge. E.g., how does plants obtain their food?

Student Activity: Students respond to teacher's questions. E.g., Plants obtain their food by absorbing minerals and water from the soil.

Content Development (20 minutes) Step 1: Meaning of Photosynthesis, raw materials and importance of photosynthesis.

Teacher activity:

a. Teacher asks students to brainstorm to come up with the meaning of photosynthesis.
b. Teacher asks students to come up with the raw materials of photosynthesis.
c. Teacher asks students to brainstorm and come out with the importance of photosynthesis.

Student activity:

a. Students brainstorm to come up with the meaning of Photosynthesis.
b. Students brainstorm to come up with the raw materials for photosynthesis
c. Students brainstorm to come out with the importance of photosynthesis.

Main Ideas

One of the most important biochemical processes on earth is photosynthesis-a process whereby living organisms prepare organic food substances (sugar) by utilizing organic molecules such as water and carbon-dioxide in the presence of chlorophyll using energy from the sun.

The raw materials for photosynthesis are water (H_20) and carbon-dioxide ($C0_2$) and the energy required to drive this anabolic process is sunlight absorbed by chlorophyll. The equation for photosynthesis is:

$$6C0_2+6H_20 \xrightarrow{\text{light}} C_6H_{12}O_6+60_2$$

The stages involved in photosynthesis are the light stage and the dark stage;

The grana is the place where the light stage occurs whiles the stroma is the place where the dark stage takes place.

Photosynthesis is very important because of the following reasons:

i. It provides food for both plants and animals

ii. It purifies the atmosphere by removing carbon-dioxide

iii. It releases oxygen into the atmosphere for aerobic respiration

iv. It is the general base for food chain or food web.

Application (20 minutes)

Teacher activity: Teacher asks students to answer the following questions in their exercise books.

- Define photosynthesis
- State two importance of photosynthesis

Student activity: students respond to teacher's questions using what they have learned.

Closure (15 minutes)

Teacher activity:

a. Teacher summarises the lesson by restating salient points.

b. Teacher evaluates the lesson using questions based on the set objectives.

Student activity: students listen to teacher and respond to teacher's questions.

Assignment

Students are asked to do the following:

1. Describe how green plants obtain their food.
2. Differentiate between nutrition in plants and nutrition in animals.

Conceptual change lesson

Week one (1)

STEP 1

Many people believe that plants eat by using their roots because all the essential nutrients required for plant growth are absorbed from the soil and transported to all other parts of the plant. State with reasons whether you consider photosynthesis as a process whereby plants obtain water and mineral salts from the soil. Write your answer in the blank space provided.

ANSWER…………………………………………………………………………
……………………………………………………………………………………
………………………………………

STEP 2

The common misconceptions and their reasons are presented in the table below.

WRONG IDEAS
1. Plants eat by using their roots because all the essential nutrients required for plant growth are absorbed from the soil and transported to all other parts of the plant.
2. The raw materials for photosynthesis are water and mineral salts because these are the most important materials for plant survival
3. Photosynthesis is important because it provides food for plants survival
Plants that are not green in color (do not contain chlorophyll) can also undergo photosynthesis because they all have roots for absorbing nutrients from the soil.
4. Photosynthesis can occur at every time of the day. This is because the plant constantly takes in carbon dioxide.

These views are wrong scientifically

STEP 3.

Right ideas

1. Plants use water and carbon dioxide in the presence of sunlight to manufacture organic food substances such as glucose.
2. The materials required for photosynthesis are water (H_20) and carbon-dioxide ($C0_2$) and the energy required to drive this anabolic process is sunlight absorbed by chlorophyll.

   The overall reaction involved in photosynthesis is:

   $6C0_2+6H_20 \longrightarrow C_6H_{12}O_6+60_2.$
3. Photosynthesis is important not because it provides plants with food but also sustains all life on earth.

4. Plants that are not green in color do not contain chlorophyll or photosynthetic pigment hence cannot undergo photosynthesis. However, some non-green plants such as brown and red algae can undergo photosynthesis because they have photosynthetic pigment which is masked by brown and red color respectively.
5. Photosynthesis can only occur during the day when sunlight is available. During the night, photosynthesis ceases and respiration takes place resulting in the release of oxygen.

STEP 4.

Reading Texts:

One of the most important biochemical processes on earth is photosynthesis-a process whereby photosynthetic organisms manufacture organic food substances (glucose) by utilizing organic molecules such as water and carbon-dioxide in the presence of chlorophyll using energy from the sun.

Water (H_20) and carbon-dioxide ($C0_2$) are the raw materials for photosynthesis, and the energy required to drive this anabolic process is sunlight absorbed by chlorophyll.

Stages are the light and dark stage. The grana is where the light stage takes place whereas the dark stage occurs in the stroma of the chloroplast.

Photosynthesis is very important because of the following reasons:

v. It provides food for both plants and animals
vi. It purifies the atmosphere by removing carbon-dioxide
vii. It releases oxygen into the atmosphere for aerobic respiration
viii. It is the general base for food chain or food web.

The chemical equation for photosynthesis is presented below:

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

STEP 5

Answer the following questions

1. Define photosynthesis

……………………………………………………………………………

2. State two importance of photosynthesis

……………………………………………………………………………

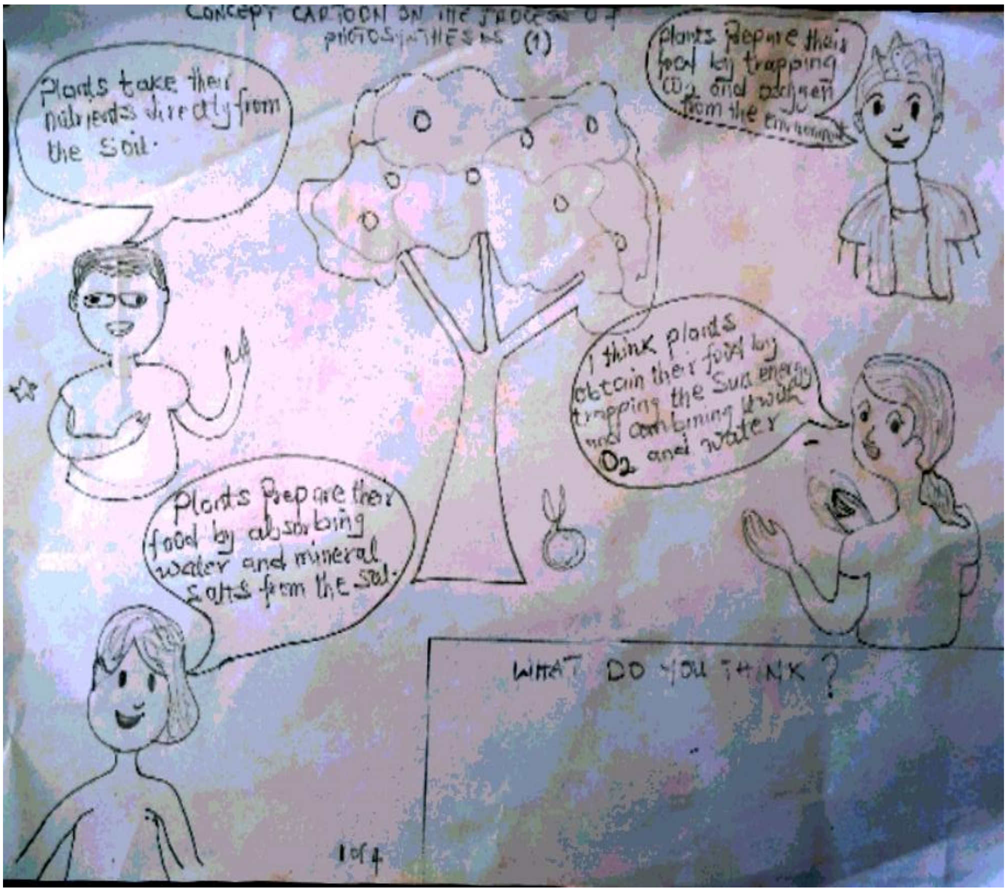
……………………………………………………………………………

3. Write a balance chemical equation for photosynthesis

……………………………………………………………………………

Concept cartoons lesson plan

WEEK ONE (1)



STEP 1.

Observe the concept cartoon above and write your idea on each of the cartoon character in the blank space provided.

…………………………………………………………………………………
…………………………………………………………………………………

STEP 2.

In a group of six, compare, argue and discuss your ideas. Write your ideas in the blank space provided

…………………………………………………………………………………
…………………………………………………………………………………

STEP 3.

One person in each group presents their ideas based on the Concept cartoons.

STEP 4. **CORE POINTS**

One of the most important biochemical process on earth is photosynthesis-a process whereby photosynthetic organisms manufacture organic food substances (glucose) by utilizing organic molecules such as water and carbon-dioxide in the presence of chlorophyll using energy from the sun.

Water (H_20) and carbon-dioxide ($C0_2$) are the raw materials for photosynthesis, and the energy required to drive this anabolic process is sunlight absorbed by chlorophyll.

Stages are the light and dark stage. The grana is where the light stage takes place whereas the dark stage occurs in the stroma of the chloroplast.

Photosynthesis is very important because of the following reasons:

i. It provides food for both plants and animals
ii. It purifies the atmosphere by removing carbon-dioxide
iii. It releases oxygen into the atmosphere for aerobic respiration
iv. It is the general base for food chain or food web.

The chemical equation for photosynthesis is presented below:

$$6C0_2 + 6H_20 \longrightarrow C_6H_{12}O_6 + 60_2.$$

Photosynthesis occur in two stages/ light stage and dark stage;

Light stage occurs in the grana of chloroplast whiles the dark stage occurs in the stroma of the chloroplast.

Photosynthesis is very important because of the following reasons:

i. It provides food for both plants and animals
ii. It purifies the atmosphere by removing carbon-dioxide
iii. It releases oxygen into the atmosphere for aerobic respiration
iv. It is the general base for food chain or food web.

The chemical equation for photosynthesis is presented below:

$6C0_2 + 6H_20 \longrightarrow C_6H_{12}O_6 + 60_2$.

STEP 5

Answer the following questions

4. Define photosynthesis

…………………………………………………………………………

5. State two importance of photosynthesis

…………………………………………………………………………

6. Write a balance chemical equation for photosynthesis

…………………………………………………………………………

Data Processing and Analysis

The data obtained from the study were coded and were presented using descriptive and inferential statistics. One-way analysis of variance (ANOVA) was used to analyse research question one which sought to determine the pre-test scores of students exposed to conceptual change texts, concept cartoons and the conventional teaching methods. This was done to establish whether all the three groups were at par in terms of their Knowledge and understanding of the concepts related to photosynthesis. One-way analysis of variance (ANOVA) was used because the data involved only one dependent variable (understanding) with three groups (concept cartoons, conceptual change texts and conventional approaches).

Paired sample t-test and bar charts were used to analyse research hypothesis one which sought to determine whether there exists significant difference between students' prior knowledge in photosynthesis and their knowledge after the intervention when taught with concept cartoons, conceptual change texts and the conventional instructional approaches. Paired sample t-test was used because each students' pre-test and post-test scores were compared to determine if there exist statistically significant difference in knowledge gain. One-way analysis of variance (ANOVA) was used to analyze research hypothesis two which sought to find out if there was any statistically significant difference in post-test scores between the concept cartoons group, conceptual change texts group and the conventional approach group. One-way analysis of variance (ANOVA) was used because the data involved only one variable with three groups (concept cartoons, conceptual change texts and conventional approach). Post-hoc using the Bonferroni multiple comparison was used to conduct further analysis to determine where the difference lay since there were three groups. The Bonferroni multiple comparison was preferred because of its simplicity and strict control over the Type I error rate. Again, the Bonferroni multiple comparison was suitable for this study because the number of comparisons in this study is small.

For research hypothesis three which sought to determine whether there exists statistically significant difference in the performance between high achievers and low achievers in the groups exposed to conceptual change texts and concept cartoons. Bar charts, Independent sample t-test and ANCOVA were used. Independent sample t-test was used to analyze the pre-test scores between high achievers and low achievers to establish whether the groups were equivalent before the intervention. ANCOVA was used to analyze the post-test scores since there were differences between the high achievers and low achievers in the pre-test scores. Using ANCOVA allowed the researcher to control these initial differences when analyzing the post-test results.

Descriptive analysis was used to analyse research question two which sought to determine students' views about the use of concept cartoons and conceptual change texts in teaching. Descriptive analysis was also used to explore students' misconceptions about photosynthesis in research question three.

Operational Definitions:

1. Conceptual Understanding: Defined as the students' ability to accurately explain and apply the core concepts of photosynthesis. This was measured through scores on the pre-test and post-test, where specific criteria (correctness of answers, depth of explanation) were used to assess understanding.

2. Misconceptions: Operationally defined as incorrect or incomplete understandings of photosynthesis that students held before the intervention. These were identified through specific patterns in pre-test responses and pre-intervention interviews, such as common errors or misunderstandings in explaining processes like photosynthesis.

3. Effectiveness of Intervention: Defined as the extent to which the concept cartoons and conceptual change texts improved students' conceptual understanding and reduced misconceptions. This was measured by the change in test scores from pre-test to post-test, and qualitatively through student responses in post-intervention interviews.

4. Performance Categories: Low-performing, average-performing, and high-performing students were categorized based on their pre-test scores. These categories guided the selection of participants for interviews and helped in interpreting the impact of the intervention across different levels of initial understanding.

CHAPTER FOUR

RESULTS AND DISCUSSION

Overview

This chapter presents and discusses the results obtained from analyses of data on effect of conceptual change texts and concept cartoons on Senior High School students' understanding of concepts related to photosynthesis with respect to the research questions and hypothesis that guided the study.

Assumption Tests

To ascertain whether the data obtained could support the use of parametric statistical tools, it was subjected to a normality test. The Kolmogorov-Smirnov test was conducted and the test value was non-significant for students' pre-test scores (sig. =0.132, ρ>0.05), and post-test scores (sig. =0.195, ρ>0.05). This shows that the pre-test and post-test scores were normally distributed and, thus, the assumption for using the parametric test was not violated (Pallant, 2007). Further, Levene's test for equality of variance was conducted to test for homogeneity of variance of the pre-test and post-test scores of students' achievement in concepts related to photosynthesis. The test was found to be non-significant for the pre-test (F (1.779), sig. =0.174, ρ>0.05) and post-test (F (.081), sig. =0.922, ρ>0.05). This indicates equality of variance. Also, Normal Q-Q plot was conducted for both pre-test and post-test scores of students' achievement scores on concepts related to photosynthesis. A normal Q-Q plot was obtained for both the pre-test and post-test scores indicating normal distribution of data. Figure 1 and 2 indicate that the pre-test and post-test were normally distributed. Therefore, from the preliminary tests results, parametric tests including One-way analysis of variance (ANOVA), Paired Sample T-test and Independent-Samples T-test could be performed (Pallant, 2007).

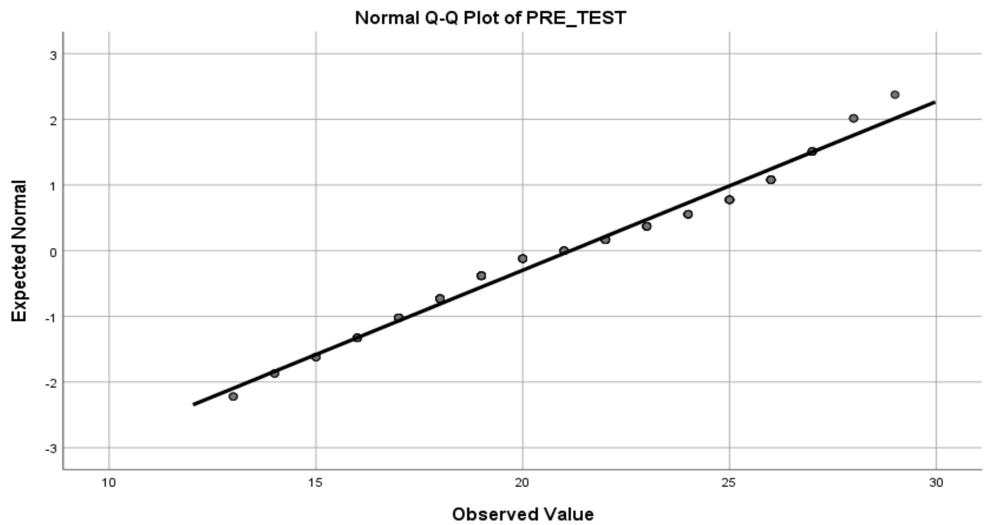


Figure 1: Normal Q-Q plot of pre-test scores of students' achievement in photosynthesis.

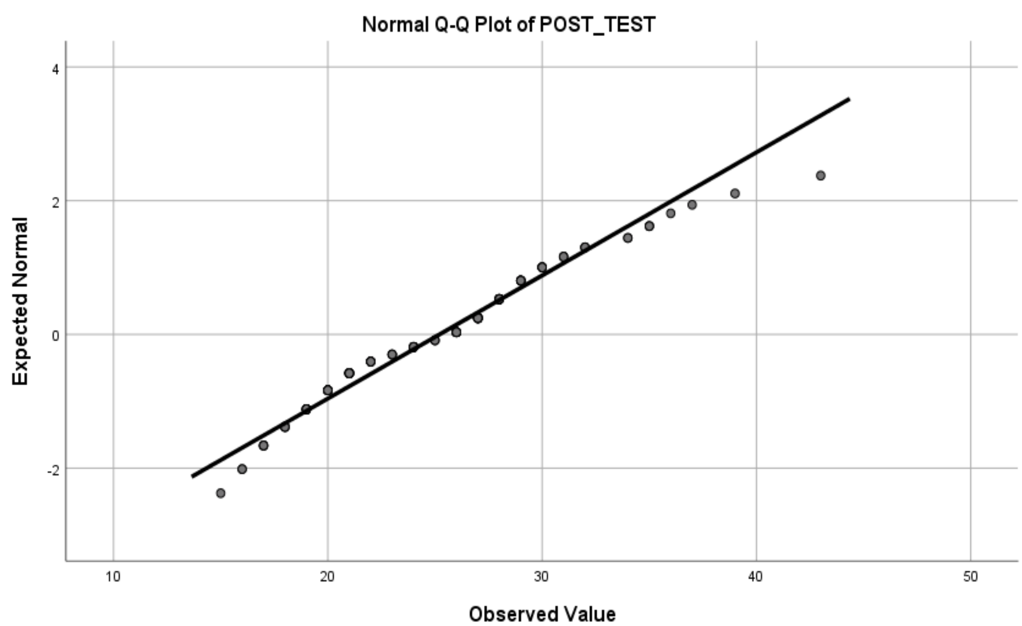


Figure 2: Normal Q-Q plot of post-test scores of students' achievement in photosynthesis.

The assumption tests for conducting ANCOVA with the concept cartoons teaching strategy confirmed that all necessary conditions were met, ensuring the validity of the analysis. The Shapiro-Wilk test verified the normality of achievement scores for both high and low achievers, with p-values of 0.351 and 0.713, respectively, indicating normally distributed data. The correlation analysis between pretest and post-test scores yielded a p-value of 0.679, confirming a linear relationship between the covariate and the dependent variable. Additionally, the homogeneity of regression slopes was supported by a p-value of 0.867, indicating consistent slopes across different achievement levels. Since the assumptions of normality, linearity, and homogeneity of regression slopes were all satisfied, ANCOVA was appropriately used, ensuring the reliability of the results in evaluating the effectiveness of the concept cartoons teaching strategy.

For the conceptual change text (CCT) group, all critical assumptions for conducting ANCOVA were verified and satisfied, ensuring the validity of the analysis. The Shapiro-Wilk test confirmed the normality of achievement scores for both low and high achievers, with p-values of 0.753 and 0.489, respectively, indicating that the data were normally distributed. The correlation analysis between pretest and posttest scores yielded a p-value of 0.591, affirming a significant linear relationship. Additionally, the homogeneity of regression slopes was confirmed with a p-value of 0.339, indicating consistency across achievement levels. As all assumptions—normality, linearity, and homogeneity of regression slopes—were met, the ANCOVA analysis was appropriately conducted, providing a reliable basis for evaluating the effectiveness of the conceptual change texts instruction in narrowing the achievement gap in understanding photosynthesis.

Research Question 1

The research question one sought to find out if there exist statistically significant difference in pre-test scores of students in the concept cartoons group, conceptual change texts group and the conventional method groups. Mean and standard deviation scores are presented in Table 2.

Table 2: *Descriptive statistics of Pre-test Means and Standard Deviations for concept cartoons (CC), conceptual change texts (CCT) and conventional method (CM)*

Group	Number	Mean	Standard Deviation
Concept cartoons	42	21.02	4.12
Conceptual change texts	33	21.21	3.40
Conventional Method	38	21.26	4.12

To ensure all groups were at par prior to the study, the pre-test scores of the concept cartoons group, conceptual change texts and conventional groups were compared using One-way analysis of variance (ANOVA). Results in Table 3 show that there was no statistically significant difference in the pre-test scores among the students in concept cartoon, conceptual change texts and conventional groups ($F(2,110) = 0.04$, $p = .96$) before the intervention. This means that knowledge of students on concepts related to photosynthesis in all three schools used for this study were at par prior to the intervention. Thus, any improvement in students' knowledge after the intervention could be attributed to it with respect to concepts related to photosynthesis.

Table 3: Results of One-way ANOVA for Pre-test of concept cartoons, conceptual change texts and conventional method

Sources	Sum of Squares	df	Mean Squares	F	*p*
Between Groups	1.27	2	0.6365	0.04	.960
Within Groups	1695.86	110	15.4169		
Total	1697.12	112			

Interval plot for the pre-test means for the three groups was determined and the results presented in Figure 3. From Figure 3, the mean interval for concept cartoons (CC), conceptual change texts (CCT) and conventional method (CM) are 21.01, 21.03 and 21.04 respectively indicating no significant differences in the pre-test mean scores prior to the intervention confirming the fact that students' prior knowledge of concepts related to photosynthesis were similar for all three groups.

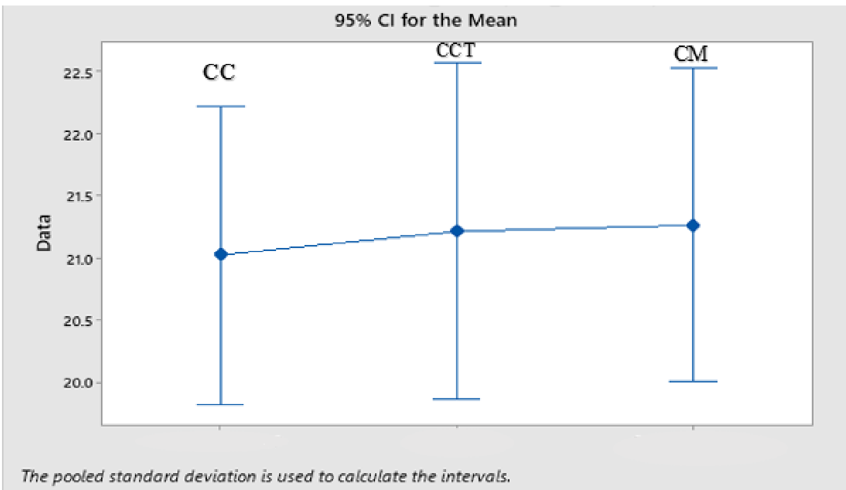


Figure 3: Pre-test Interval plot of concept cartoons, conceptual change texts and conventional method.

Research Hypothesis 1

The first research hypothesis sought to determine whether there exists a significant difference between students' prior knowledge and their knowledge after they were taught with concept cartoons and conceptual change texts teaching approaches. This was to determine whether the intervention could help improve their conceptual understanding of concepts related to photosynthesis. To achieve this, bar charts and Paired Sample t-tests were used to analyze the pre-test and post-test scores of the groups taught with concept cartoon, conceptual change texts and Conventional instructional approaches.

Figure 4 shows that the post-test scores of students taught with concept cartoons instructional strategy were relatively higher than their pre-test scores.

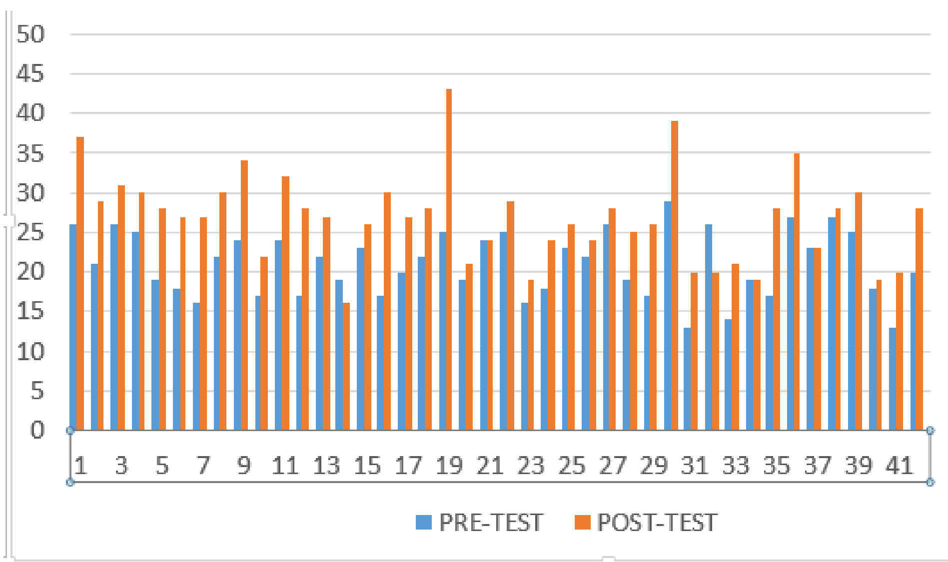


Figure 4: Chart showing pre-test and post-test scores of participants in the concept cartoons group.

Also, Figure 5 shows that the post-test scores of students on concepts related to photosynthesis were higher compared with pre-test scores for those exposed to the Conceptual change texts instructional strategy.

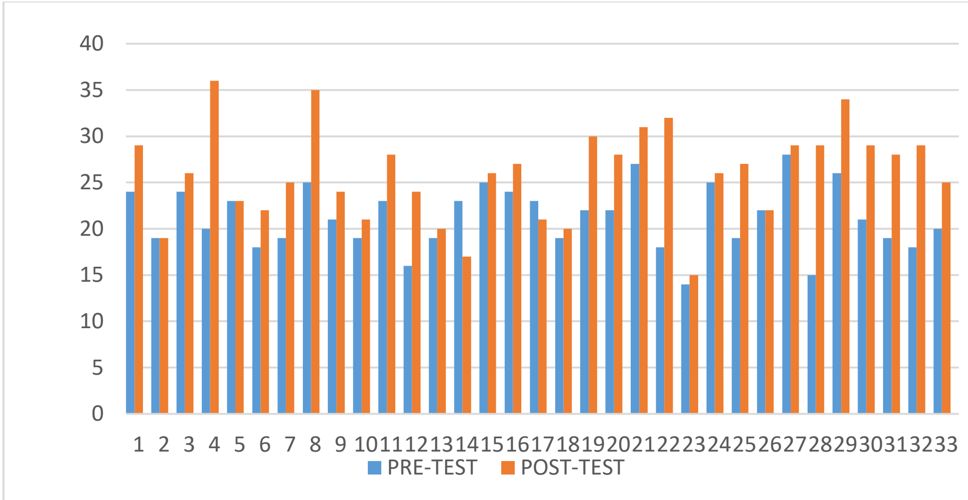


Figure 5: Chart showing the pre-test and post-test scores of participants in the conceptual change texts group.

Figure 6 shows that the post-test scores on students' performance on concepts related to photosynthesis appeared relatively higher than their corresponding pre-test scores for the group exposed to the Conventional Teaching approach.

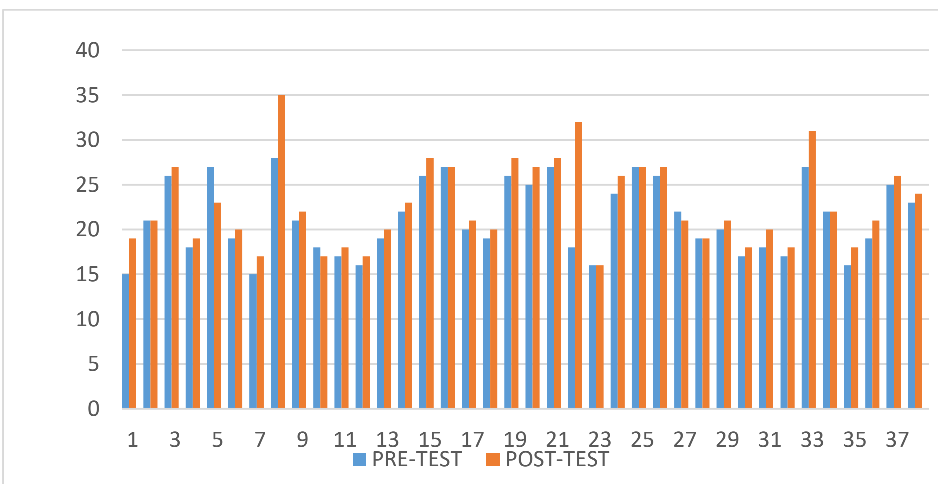


Figure 6: Chart showing the pre-test and post-test scores of participants in the Conventional method group.

Table 4 shows that there were gains in students' knowledge (improvement) after they were instructed using the concept cartoons, conceptual change texts and Conventional approaches. The percentage gain scores for concept cartoons, conceptual change texts and conventional instructions are 11.69%, 9.57% and 3.0% respectively.

Table 4: Pre-test-Post-test Means, Standard Deviations and differences (knowledge gain) for concept cartoons (CC), conceptual change texts (CCT) and conventional method (CM)

	Pre-test			Post-test		
Group	n	M	SD	M	SD	Difference (%)
CC	42	21.02	4.12	26.86	5.65	11.65
CCT	33	21.21	3.40	25.97	5.02	9.57
CM	38	21.26	4.12	22.74	4.72	3.0

Note: The values for the difference column are the changes in the mean percentage correct scores from the pre-test to the post-test.

To ascertain whether the differences in gained scores (knowledge gain) recorded were statistically significant, a Paired sample t-test was used to analyze the pre-test and post-test scores and the results reported in Table 5. The table reveals that students taught with the concept cartoons showed statistically significant difference in the post-test (*M* =26.86, *SD* = 5.65) than the pre-test (*M* = 21.03, *SD* = 4.13), t (28) = 8.34, $p < .05$). Similarly, the students taught with the conceptual change texts showed statistically significant higher post-test (*M* = 25.97, *SD* = 5.02) than the Pre-test (*M* = 21. 21, *SD* =3.40), t (28) = 5.56, $p < .05$). The results from the table also shows that students taught with the conventional method experienced slightly significant post-test (*M* =21.26, *SD* = 4.12) than the pre-test (*M* = 22.74, *SD* = 4.72), t (28) = 3.42, $p < .05$).

The significance of the paired sample t-test indicates that there exists statistically significant difference in the gain scores (i.e. knowledge gain) of students' in understanding of concepts related to photosynthesis after the intervention.

Table 5: Results of Paired Sample T-test for each treatment group (concept cartoons, conceptual change texts and conventional method)

Group	Measure	N	Mean	SD.	t	df	p
CC	Pre-test	42	21.02	4.13	-8.34	28	0.000
	Post-test	42	26.86	5.65			
CCT	Pre-test	33	21.21	3.40	-5.56	28	0.000
	Post-test	33	25.97	5.02			
CM	Pre-test	38	21.26	4.12	-3.42	28	0.002
	Post-test	38	22.74	4.72			

*Significant, since $p < 0.05$

Source: Field survey (2022).

Responses and explanations of concepts prior to and after the interventions were qualitatively explored to gain more insights into the extent of the improvement of students' conceptual understanding of concepts related to photosynthesis after the intervention. For instance, a student from the concept cartoons group initially responded that plants prepare their food using carbon-dioxide and oxygen, "*carbon-dioxide and oxygen are the molecules needed to combine with RuBP in the dark stage to produce sugar*". However, after the intervention, he selected the correct response in the post-test item (Plants prepare their food by absorbing carbon-dioxide and water in the presence of sunlight) explaining that, "*water is* *needed to produce hydrogen ions which is converted to hydrogen atom which is used to reduce a hydrogen acceptor called Nicotinamide adenine dinucleotide phosphate (NADP) to form reduced Nicotinamide adenine dinucleotide phosphate (NADPH2), Chlorophyll is needed to trap the sunlight whiles sunlight is needed to release energy which causes the combination of inorganic phosphorus (pi) and ADP to form ATP for use in the dark stage*".

A student in the conceptual change texts group who could only identify the chemical equation for photolysis of water in the pre-test but could not explain why the equation represented photolysis of water showed significant improvement in understanding when she responded in the post-test, "*The equation above illustrate photolysis of water because during photolysis of water, water molecule is splitted into hydrogen ion and hydroxide ion*".

Finally, participant 4 in the conventional approach group initially selected oxygen as the compound in the light stage needed in the dark stage. However, he selected the correct response (NADPH2) in the post-test explaining that, "*NADPH2) is the compound needed in the dark stage because Phosphoglyceric Acid (PGA) combines with hydrogen supplied by NADPH2 (from light stage) to form PGAL (Phosphoglyceraldehyde), a 3C sugar*.

These correct explanations provided by the students after the intervention show significant improvement (knowledge gain) in conceptual understanding of concepts related to photosynthesis.

Research Hypothesis 2

The second research hypothesis sought to determine if there exist significant difference in the post-test scores of students taught concept cartoons, conceptual change texts and conventional method. To compare the post-test scores of the three groups, One-way analysis of variance (ANOVA) was used. The mean and Standard deviation of scores is presented in Table 6.

Table 6: Descriptive statistics of Post-test Means and Standard Deviations for concept cartoons (CC), conceptual change texts (CCT) and conventional method (CM)

Group	Number	Mean	Standard Deviation
Concept cartoons	42	26.86	5.66
Conceptual change texts	33	25.97	5.02
Conventional Method	38	22.74	4.72

The ANOVA results in Table 7 shows that there is a statistically significant difference among the post-test scores of the conceptual change group, the concept cartoon group and the conventional group (F (2,110) = 6.84, $p < .05$).

Table 7: Results of One-way ANOVA for Post-test of Concept cartoon, conceptual change texts and conventional approach groups

Sources	Sum of Squares	df	Mean Squares	F	*p*
Between Groups	365.4	2	182.71	6.84	0.002
Within Groups	2939.5	110	26.72		
Total	3304.9	112			

*Significant, since $p < 0.05$

Interval of the mean post-test scores for the three groups was determined using Box plot and results presented in Figure 7. From the figure, it can be seen that the interval between concept cartoons (CC) and conceptual change texts (CCT) group differ from that between the conceptual change texts and conventional method (CM) group indicating differences in the mean post-test scores. It can be seen from the figure that the interval between the concept cartoons (26.8) and the conceptual change texts (26.0) group is closer than that between concept cartoons group and conventional method (22.5) group and that between conceptual change texts group and the conventional method group.

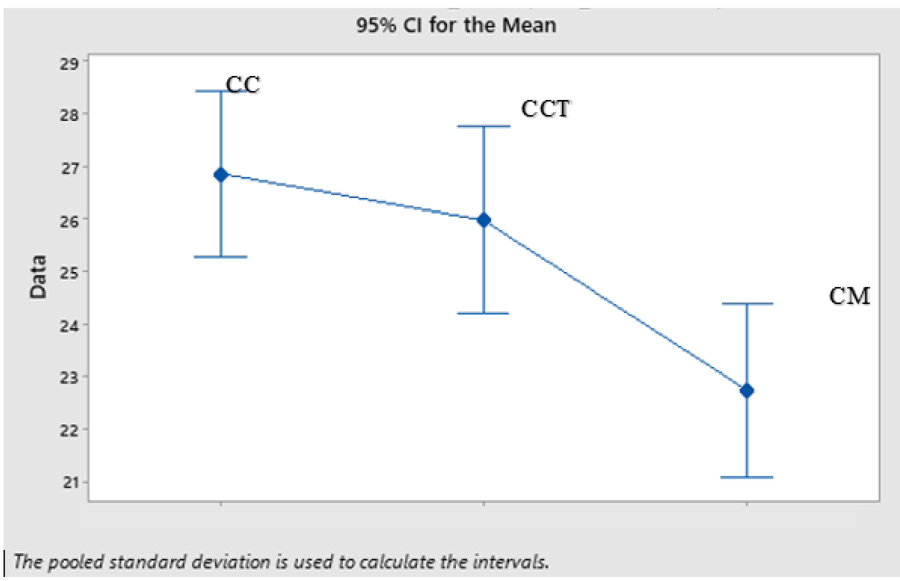


Figure 7: Post-test Interval plot of Concept cartoons (CC), conceptual change texts (CCT) and conventional method (CM).

The Tukey simultaneous confidence intervals plot was used to determine the mean differences between the three groups in order to ascertain whether the corresponding means were different. The results from the analysis are presented in Figure 8. From the figure, the mean difference between participants in the concept cartoons and conceptual change texts group is -1 and that between concept cartoons and conventional method is -4.2 whiles that between conceptual change texts group and conventional method is -3.3.

According to the Tukey simultaneous confidence interval plot, if an interval does not contain zero, the corresponding means are significantly different. Therefore, it can be concluded that significant difference exist in the mean post-test scores for all the three groups since none of the mean differences was zero.

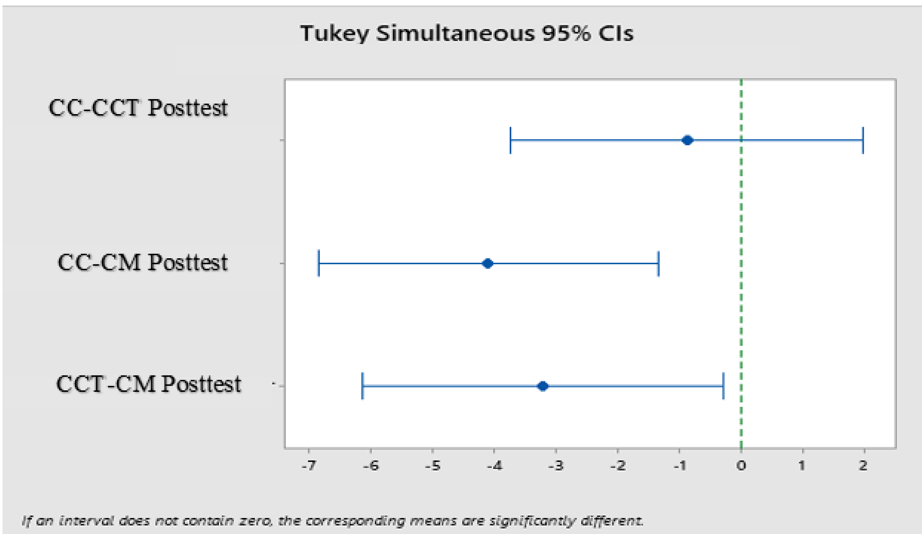


Figure 8: Tukey simultaneous confidence intervals showing difference of means for concept cartoons (CC), conceptual change texts (CCT) and conventional method (CM).

NB: If an interval does not contain zero, the corresponding means are significantly different.

Post-hoc analysis using the Bonferroni comparisons was used to conduct further analysis to determine where the difference in mean post-test scores existed since there were three groups. From the results in Table 8, it can be seen that there was no statistically significant difference in the post-test scores between the Concept cartoons group (26.86, SD = 5.65) and the conceptual change texts group (M = 25.97, SD =5.02, *p* =1.000). There was, however, a statistically significant difference in the post-test scores between the concept cartoons group (26.86, SD = 5.65) and the conventional group (M = 22.74, SD = 4.72, *p* = .002). This indicates that students in the concept cartoons group outperformed their counterparts in the conventional group. Again, there was a statistically significant difference in the post-test scores between the Conceptual change texts group (M = 25.97, SD =5.0) and the conventional group (M = 22.74, SD = 4.72, *p* = .0029). This also shows that students in the Conceptual change texts group outperformed significantly better than those in the conventional group.

To determine the magnitude of the difference in the post-test scores among the concept cartoons, conceptual change texts and conventional group, the effect size was calculated using partial eta squared. An effect size index of .270 was obtained. According to Cohen, Manion and Morrison (2017), an effect size of .270 indicates a large difference among the post-test scores of the concept cartoons, conceptual change texts and conventional groups.

The results show that students taught with the concept cartoons and the conceptual change texts had equal understanding of photosynthesis after the intervention. Also, it further indicates that students taught with concept cartoons and conceptual change texts outperformed their counterparts in the conventional group. Hence, this finding buttress those who reported that conceptual change codels particularly concept cartoons and conceptual change texts enhance students' conceptual understanding of concepts related to photosynthesis (Akamca et al., 2009; Esra & Ponar, 2010).

Table 8: Post Hoc Analysis of Post-test Scores for concept cartoons Group (CC), conceptual change texts group (CCT) and conventional Group (CG) Using Bonferroni Test

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence interval for Difference	
					Lower Bound	Upper Bound
CC	CCT	.887	1.202	1.000	-2.036	3.8109
	CG	4.120*	1.1573	.002	1.3066	6.934
CCT	CC	-.887	1.202	1.00	-3.810	2.036
	CG	3.233*	1.230	.029	.243	6.223
CG	CC	-4.120*	1.157	.002	-6.934	-1.306
	CCT	-3.233*	1.230	.029	-6.223	-.243

*Significant, since $p < 0.05$

Research Hypothesis Three (3)

The third research hypothesis sought to determine whether there exists statistically significant difference in the performance of high and low achievers in the groups exposed to conceptual change texts and concept cartoons. The categorization of high and low achievers was based on students' performance in the pre-test scores. Those below the average score were classified to be lower achievers and those above as higher achievers. This research hypothesis was answered using descriptive and inferential statistics such as Bar Chart and Independent-sample t-test respectively to analyze the pre-test scores. Analysis of covariates (ANCOVA) was used to compare the post-test scores of high achievers (HA) and low achievers.

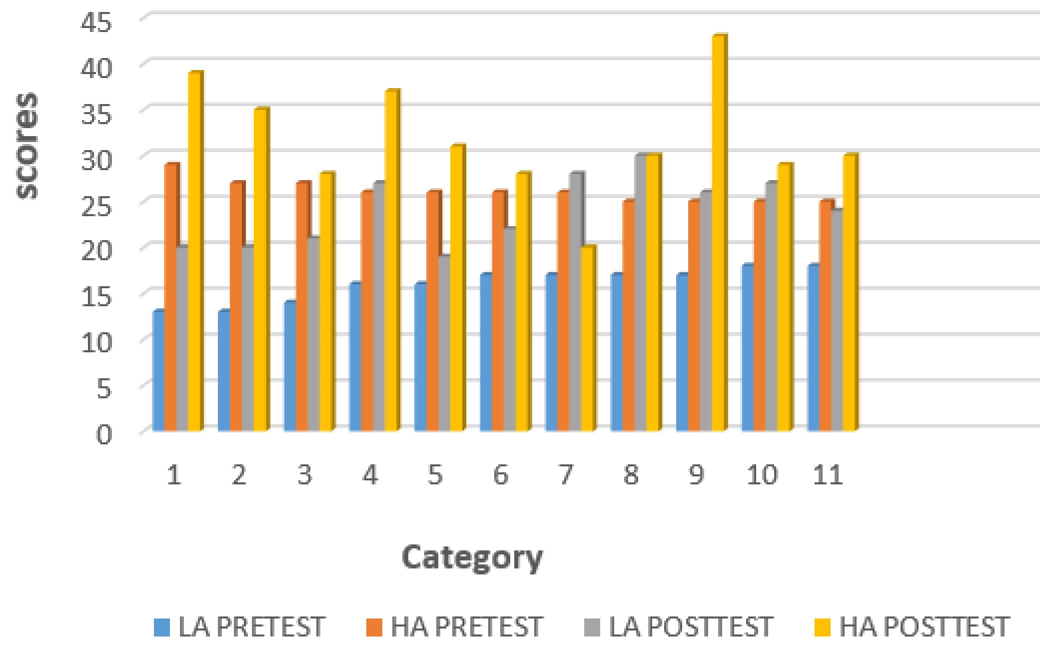


Figure 9: Chart showing pre-test and post-test scores for both high achievers and low achievers on Concept cartoons instruction.

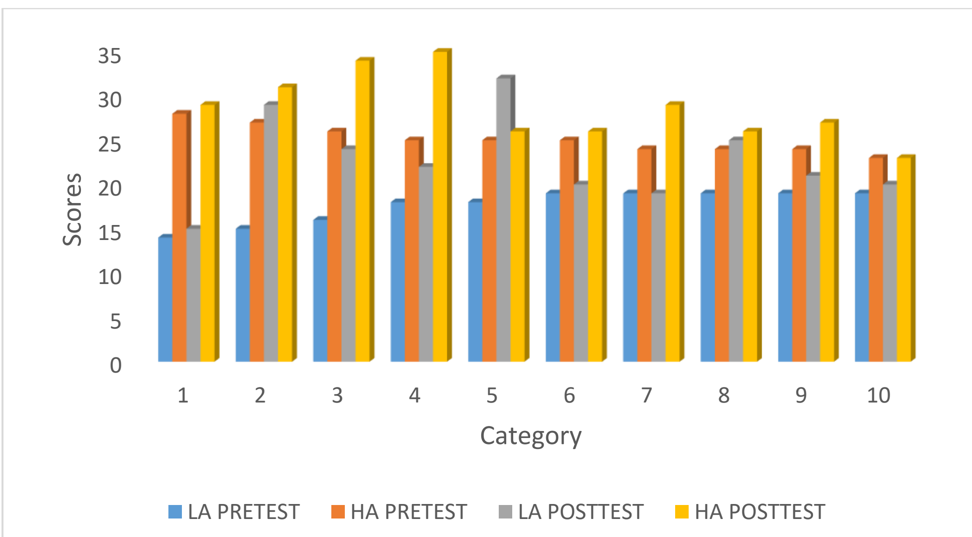


Figure 10: Chart showing pre-test and post-test scores for both high achievers and low achievers on Conceptual change texts instruction.

For students taught with concept cartoons and conceptual change texts instructional approaches, it can be seen in Figures 9 and 10 that the pre-test scores of students in the high-achieving groups were higher compared with their counterparts in the low-achieving group. It appears that high achievers performed better than their counterparts in the low-achieving groups prior to the intervention. However, as seen from Figures 9 and Figure 10, the gap between the pre-test scores of the high and low achievers had narrowed in the post-test scores, indicating an improvement in knowledge among participants in the low achieving groups after the intervention.

To determine whether the differences observed in the descriptive statistics were statistically significant, an Independent-sample t-test was used to compare the pre-test scores of low and high achievers in the conceptual change texts and concept cartoons group.

Table 9: *Results of Independent-Sample t-test for Pre-test Scores of Low and High Achievers in the concept cartoons Group (CC) and conceptual change texts (CCT) groups.*

Variable	Achievement level	N	Mean	t	df	p
Pre-test	Low achievers in CC	11	16.00	15.13	20	.000*
	High achievers in CC	11	26.09			
Pre-test	Low achievers in CCT	10	17.60	9.75	18	.000*
	High achievers in CCT	10	25.10			

*Significant, since $p < 0.05$.

Source: Field survey (2022)

For students taught with the concept cartoons instructional approach, Table 9 shows that there was statistically significant difference in the pre-test scores between the low achieving group (M = 16.00, SD = 1.84) and the high achieving group (M = 26.09, SD = 1.22, t (20) = 15.13, $p < .05$). Similarly, for students taught with conceptual change texts instructional approach, Table 9 shows that there was statistically significant difference in the pre-test scores between the low achievers (M = 17.60, SD = 1.90) and the high achievers (M = 25.10, SD = 1.52, t (18) = 9.75, $p < .05$). The statistically significant differences in the pre-test scores for both concept cartoons and conceptual change texts groups indicate that, before the intervention, there was a clear achievement gap between high and low achievers. The high achievers performed better than the low achievers in the pre-tests under both teaching strategies. This result implies that both groups had a different starting point in terms of their understanding of photosynthesis before the instructional intervention was applied.

To assess the effectiveness of the concept cartoons and the conceptual change texts teaching strategies in bridging the achievement gap between high and low achievers, an Analysis of Covariance (ANCOVA) was performed on the posttest scores, with pretest scores used as a covariate. This analysis aimed to assess whether the gap between high and low achievers had been reduced after the intervention. The ANCOVA results in Table 10 indicate that there is no statistically significant difference in post-test scores between high achievers and low achievers, ($F (1, 19) = 0.456$), ($p = 0.508$), (partial $\eta^2 = 0.023$). The concept cartoons teaching strategy explained approximately 47.3% of the variance in post-test scores (partial $\eta^2 = 0.473$); Adjusted (partial $\eta^2 = 0.418$). Given that there was a significant difference in pre-test scores, but no significant difference in post-test scores, it can be concluded that the concept cartoons teaching strategy was effective in narrowing the performance gap between high and low achievers. The low achievers' performance improved to a level comparable to that of the high achievers, indicating that the intervention was successful in equalizing the students' understanding and knowledge after the teaching period.

Table 10: *Results of ANCOVA for Post-test Scores of Low and High Achievers in the concept cartoons Group (CC) group.*

Source	Type III Sum of Squares	df	Mean Square	F	Sig	Partial Eta Squared
Corrected Model	415.238[a]	2	207.619	8.528	.002	.473
Intercept	.146	1	.146	0.006	.939	.000
CCGprete	79.056	1	79.056	3.247	.087	.146
CCGach	11. 093	1	11. 093	.456	.508	.023
Error	462.580	19	24.346			
Total	18014.000	22				
Corrected Total	877.818	21				

* None Significant, since p >0.05.

Source: Field survey (2022).

The ANCOVA results, as shown in Table 11, indicate that the difference in post-test scores between high achievers and low achievers was not statistically significant after the conceptual change texts instruction ($F (1, 17) = 0.171$, $p = 0.685$, partial $\eta^2 = 0.010$). The significance value ($p > 0.05$) suggests that the initial disparity in understanding between the two groups was mitigated following the intervention. The small effect size (partial $\eta^2 = 0.010$) further supports this finding, indicating that only 1% of the variance in post-test scores can be attributed to the difference in achievement levels.

Table 11: *Results of ANCOVA for Post-test Scores of Low and High Achievers in the conceptual change texts (CCT)group.*

Source	Type III Sum of Squares	df	Mean Square	F	Sig	Partial Eta Squared
Corrected Model	187.931[a]	2	93.965	4.690	.024	.356
Intercept	25.308	1	25.308	1.263	.277	.069
CCGprete	13.881	1	13.881	.693	.417	.039
CCGach	3.422	1	3.422	.171	.685	.010
Error	340.619	17	20.036			
Total	13687.000	20				
Corrected Total	528.550	19				

*None Significant, since p >0.05.

Source: Field survey (2022)

Research question 2

The research question two sought to determine students' view concerning the utilization of concept cartoons and conceptual change texts in teaching and learning. To explore student's views on the use of these teaching approaches, semi-structured interview was used. Six (6) students were selected from each experimental group and interviewed individually. The transcribed responses were analyzed descriptively. Findings of related concepts that were repeated were brought together as a theme. Generally, four themes emerged from the responses comprising improvement of understanding, motivation, class participation and interesting/funny.

For students interviewed on the concept cartoons instructions, they reported the use of concept cartoons instruction had improved their understanding of the concept of photosynthesis. For instance, student (1) answered by saying that "I *think my understanding of photosynthesis has greatly improved after the concept cartoons lessons, initially I had some misconceptions about photosynthesis but after using the cartoons I have understood the concept very well*". Some students also indicated that concept cartoons instruction motivated them to learn the concept of photosynthesis. According to student (2), "*I was really motivated by the drawings in the concept cartoons to learn the concept although I initially thought it was very difficult concept*". Students also revealed that the concept cartoons instruction helped them to participate in the lesson and resulted in their understanding of the concept. From student (3), "*I normally do not participate in class discussion but the group discussion of the concept cartoons helped me to participate in the lesson*". Although students considered concept cartoons instructional approach to be interesting and funny, however, some students were of the view that the steps involved are time demanding and not very helpful for slow learners. Student 4 replied that, "*This teaching strategy is time involving and requires more time than the Conventional teaching method*".

For students interviewed on the conceptual change texts instruction, students reported that it affected their understanding positively. Student (1) responded that, "*the conceptual change texts has really impacted my learning of photosynthesis because I considered it too difficult concept but this approach made it easy for me to learn it*". Some students interviewed also claimed the conceptual change texts had improved their understanding of the concept. Speaking on this, student (3) replied, "*The conceptual change texts gave us the opportunity to brainstorm and come out with our initial conceptions of the topic before the correct answers were introduced. After reading the text, I realized I had some misconceptions about photosynthesis. For instance, I have always thought plants use mineral salts from the soil to help them prepare their food. In fact, this approach has really helped me to understand this topic and I wish our teacher uses it to teach us*". Some of the students interviewed also reported that conceptual change texts had motivated their learning. Student (4) responded, "*I was challenged to bring out what I knew before the correct answers were provided with reasonable explanations. I was happy when I realized some of my initial conception of photosynthesis was correct*". It was however reported by some students that conceptual change texts instruction is expensive and not learner friendly. "*This teaching strategy is expensive because it brings extra cost to the teacher and the students as well because you had to print all these texts for every student while some of us had to make copies for ourselves. This means if one does not have money then it presents a challenge for such student to participate*".

Research question 3

To identify misconceptions Senior High School students, hold regarding photosynthesis, research question three was explored descriptively by comparing the misconceptions observed in the two-tier diagnostic pre-test to those identified in the two-tier diagnostic post-test in both experimental and control groups. The common misconceptions identified were: (1) Plants prepare their food by using their roots to obtain water and mineral salts from the soil; (2); The dark stage of photosynthesis is essentially the reduction of ribulose biphosphate(RuBp) to carbon dioxide and oxygen; (3) The dark stage of photosynthesis occurs independently of the light stage; (4) Only green leaves can photosynthesize.

It was revealed that misconceptions recorded before the intervention for concept cartoons and conceptual change texts groups had dropped significantly. However, it was observed that students in the conventional method group retained misconceptions on concepts related to photosynthesis after the intervention.

Discussion

Research question one

This research question sought to determine if there was statistically significant difference in the mean pretest scores of SHS students' performance in photosynthesis before and after intervention using concept cartoons, conceptual change texts and conventional method. Results obtained show that there were no differences in students' achievement level prior to the intervention. This means that knowledge of students on concepts related to photosynthesis in all three schools used for this study were at par prior to the intervention. Thus, any improvement in students' knowledge after the intervention could be attributed to it with respect to concepts related to photosynthesis. This uniformity is crucial as it establishes a fair starting point for assessing the impact of the teaching interventions. Given the equal baseline, any post-intervention differences in students ‘performance can be attributed more confidently to the instructional methods used rather than pre-existing differences in knowledge. This finding is consistent with the study by Treagust (1987), who establish a baseline measure to ensure differences in post-intervention scores are due to the instructional approach rather than initial student differences.

Research hypothesis one

The first research hypothesis sought to determine whether there exists a significant difference between students’ prior knowledge and their knowledge after they were taught with concept cartoons and conceptual change texts teaching approaches. The significant improvement in students’ posttest scores strongly suggests that the teaching methods employed were effective in enhancing students’ conceptual understanding of photosynthesis. The fact that the gain in knowledge was statistically significant implies that the observed improvements were not due to random chance, but rather to the targeted instructional strategies. These results affirm the value concept cartoons and conceptual change texts as powerful tools in addressing and correcting misconceptions in scientific concepts. By engaging students in a more interactive and reflective learning process, these methods seem to facilitate deeper understanding, which is essential for mastering complex biological processes like photosynthesis.

Research hypothesis 2

The second research hypothesis sought to determine if there exist significant difference in the post-test scores of students taught concept cartoons, conceptual change texts and conventional method. To compare the post-test scores of the three groups, One-way analysis of variance (ANOVA) was used. The results show that students taught with the concept cartoons and the conceptual change texts had equal understanding of photosynthesis after the intervention. Also, it further indicates that students taught with concept cartoons and conceptual change texts outperformed their counterparts in the conventional group. Hence, this finding buttress those who reported that conceptual change models particularly concept cartoons and conceptual change texts enhance students' conceptual understanding of concepts related to photosynthesis (Akamca et al., 2009; Esra & Ponar, 2010).

The finding that students taught with concept cartoons perform better than their counterparts in the conventional approach is consistent with a study conducted by Akamca et al. (2009). It also agrees with that of Ekici et al., (2007) who determined how concept cartoons could be used to diagnose and overcome student's misconceptions related to concepts in photosynthesis, and reported that concept cartoons were effective not only for identifying students' misconceptions, but also, to overcome them. The finding also corroborates with a study by Esra (2013) who studied on the effect of concept cartoon on students' achievement and attitudes towards endocrine system in biology and indicated that concept cartoons was effective tool in improving upon students' achievement in the concept. The assertion that concept cartoon is an effective tool which enhance students' conceptual understanding in difficult biological concepts particularly such as photosynthesis is also buttressed by Kabapinar (2005) who determined the effectiveness of concept cartoons and how it could be used to enhance teaching by investigating students' ideas through written probes and activities occurring in the classrooms. The findings of the case studies revealed that the concept cartoons were useful for discovering the ideas students bring to the classroom. Secondly, she reported that concept cartoons instructional approach is a better way of identifying the reasons for students' misconception through the creation of focused, especially when thought-provoking questions are used by teachers. She also reported from her study that teaching through concept cartoons is effective in dealing with the misconceptions many students hold relating to a particular concept. Balim, Inel and Evrekli (2008) also investigated the effects of concept cartoons on students' enquiry learning skill and found out that concept cartoons had positive effect on students' enquiry learning skill perceptions because it helped students with their existing experiences to gain new knowledge.

Basically, the claim by Esra (2013), Kabapınar (2005), Akamca et al., (2009), Ekici et al., (2007) and Balim et al., (2008) which this study support are: concept cartoons (1) is effective in identifying students' misconceptions within in a moment, (2) offer students the chance to deliberate on the reasons for these misconceptions, (3) provides an enhancing atmosphere that enable all students' participation in classroom activities, motivate students to support their ideas, and ultimately (4) diagnoses students' misconception and provides effective ways of bring about a conceptual change (Akamca et al., 2009).

Kabapinar, (2005) is of the view that the stages of concept cartoons teaching approach involving: cartoons presentation, discussion, ideas investigation, ideas re-interpretation, the quality of in-class discussions, opportunity for students to compare their knowledge with those in the cartoons and the teacher's role during these processes make Concept cartoons a better teaching approach than the Conventional method where the teacher serves as a dispenser of knowledge whiles students on the other end are considered as recipients (Ekici et al., 2007).

It was observed from the study that students in the concept cartoons group were more motivated, paid attention and participated significantly throughout the intervention. This is compatible with the report of Ekici et al. (2007), who stated that concept cartoons were effective in motivating students, increased their attention in the classroom and provided environment where constructivist learning can take place and where students can comfortably and greatly contribute during classroom discussions. concept cartoons facilitate motivation, creates an atmosphere for quality practical work, and reduces mismanagement during teaching and learning due to its ability to sustain students' attention throughout the lesson (Akamca et al., 2009).

Concept cartoons is a better way of teaching science than the conventional method since the visual nature makes information processing much easier (Esra, 2013). They affirmed the assertion that "a picture speaks a thousand words". Therefore, because concept cartoons present concepts pictorially, it is recommended as an effective educational device for arriving at a conceptual change since it is argued that more learning occurs when people see than when they hear. From the point of view of Esra (2013), concept cartoons are an effective not only because of its ability to simplifying difficult concepts but also because of its entertaining nature. He also pointed out that difficult concepts can be de-mystified whereas abstract concepts can be brought closer to reality when concept cartoons are utilized in the teaching process. They also maintained that using concept cartoons in teaching can reveal many facts at a glance.

The results of this study also show the effectiveness of the conceptual change texts in improving students' conceptual understanding of photosynthesis as compared to the conventional approach. The result of this study is similar to the study of Alkhawaldeh (2019) who explored the effects of conceptual change texts and conventional instructions on promoting understanding of photosynthesis and respiration in plants. The results indicated that conceptual change texts treatment groups performed significantly better than those in the conventional instruction groups. Balci et al., (2006) established from their study on photosynthesis and respiration that students' achievement in photosynthesis had increased significantly compared to those in the conventional instruction group, indicating that the Conceptual change texts is more potent in facilitating a conceptual change in students. The finding of this study is also consistent with the results of a study by Cepni and Emine (2010) whose worked on the effect of conceptual change texts on students' understanding of aspects related to the nature of science showed that it positively impacted students' learning in a Secondary School in Trabzon, Turkey. The results of a study by Armagan et al., (2017) also supports the claim that Conceptual change texts is effective in enhancing conceptual understanding of students when they determined that it improved the academic achievement of students and concluded that conceptual change texts was not only effective in addressing students' conceptual difficulties but was also successful in promoting the conceptual understanding of students.

Cepni and Emine (2010) insisted that conceptual change texts are effective in improving the academic performance of students because of its ability to activate students' existing conceptions, introduce misconceptions, and promote students understanding of abstract scientific concepts. conceptual change texts, according to Cakir, Geban and Yuruk (2002) is one of the best strategies for providing permanent Conceptual changes. Yuruk and Geban (2001) also reported that conceptual change texts instructions were better instructional approach in acquiring scientific concepts than that of the conventional method.

There seems to be enough evidence from literature in science education to support the claim that students taught with concept cartoons and conceptual change texts are better instructional approach than the conventional approach. Generally, concept cartoons and the conceptual change texts approaches are predominantly effective in improving performance and conceptual understanding of students in all subject areas and at every level of academic discipline.

Research hypothesis 3

The third research hypothesis sought to determine whether there exists statistically significant difference in the performance of high and low achievers in the groups exposed to conceptual change texts and concept cartoons. The findings from this study suggest that the concept cartoons teaching strategy is an effective tool for addressing disparities in student achievement, particularly in closing the gap between high and low achievers. The significant difference observed in pre-test scores highlights the initial knowledge disparity between the groups, which was effectively mitigated by the intervention, as evidenced by the lack of a significant difference in post-test scores. Concept cartoons are designed to be visually appealing and engaging, which can stimulate interest and motivation among students. This increased engagement may have contributed to improved understanding and retention of the material, particularly for low achievers who may have struggled with conventional instructional methods (Kose, 2008).

The strategy promotes cognitive conflict by presenting common misconceptions alongside correct scientific concepts. This encourages students to reflect on their prior knowledge and misconceptions, leading to deeper understanding and conceptual change (Keogh & Naylor, 1991). This approach may be particularly beneficial for low achievers, who might need more scaffolding to develop accurate scientific understanding. Additionally, concept cartoons often foster discussion and collaboration among students, which can enhance learning through peer interactions. This collaborative environment may provide low achievers with additional support from their peers, helping them to reach the same level of understanding as high achievers (Zembylas, 2005).

These findings suggest that the conceptual change texts strategy was effective in bringing both high achievers and low achievers to a comparable level of understanding of photosynthesis. The post-intervention scores reflect a narrowing of the gap that previously existed between these groups, which can be interpreted as a successful outcome of the teaching strategy. The effectiveness of the conceptual change texts strategy in bridging the achievement gap can be attributed to several key factors. Firstly, conceptual change texts are designed specifically to address and correct students' misconceptions, which are often the root cause of learning difficulties in photosynthesis (Gafoor, 2013). By presenting information that directly confronts and refutes these misconceptions, conceptual change texts enable both high and low achievers to reconstruct their understanding more effectively. This targeted approach ensures that all students, regardless of their prior achievement level, are guided toward a more accurate and scientifically sound understanding of photosynthesis (Hewson & Hamlyn, 1984).

Secondary, conceptual change texts strategy encourage deeper cognitive engagement by challenging students' existing beliefs and prompting them to actively reconcile new information with their prior knowledge. This engagement is particularly beneficial for low achievers, who may struggle with passive learning approaches. By fostering active participation and critical thinking, this teaching strategy helps these students catch up with their higher-achieving peers (Delucchi, 2012). Ozdemir and Clark (2007) are of the view that the structured nature of Conceptual change texts, which often include step-by-step explanations and opportunities for reflection, provides the necessary scaffolding for all students. High achievers benefit from the reinforcement of their understanding, while low achievers receive the support needed to overcome their initial challenges. This scaffolding helps to level the playing field, ensuring that all students can achieve a similar level of comprehension. Lastly, conceptual change texts, according to Balci et al. (2006) create an inclusive learning environment where all students are encouraged to engage with the material at their own pace. The differentiation embedded within the texts allows for personalized learning experiences, catering to the diverse needs of both high and low achievers. This inclusivity is key to minimizing the achievement gap, as it ensures that every student has the opportunity to succeed.

Research question 2

The research question two sought to determine students' view concerning the utilization of concept cartoons and conceptual change texts in teaching and learning. Generally, the results of the study indicate that students in both experimental groups had positive views concerning the utilization of concept cartoons and conceptual change texts instruction. The finding from this study resonates with a similar study by Taslidere (2021) who studied on the effect of conceptual change texts with concept cartoons and 5E learning model with Simulation Activities on Pre-Service Teachers' conceptual understanding. The results of the study also show that the conceptual understanding of students had improved in both concept cartoons group and conceptual change texts group. It seems that the cartoons might have excited students more and also activated their prior knowledge and brought about dissatisfaction which subsequently resulted in students being eager to fully participate in the learning (Gafoor & Shilna, 2013). The presentation of ideas through cartoon characters might have helped students in the conceptual change texts group to concretize the concepts of photosynthesis more (Taslidere, 2021). The provision of reading texts, wrong conceptions and the presentation explanations that were more plausible, intelligible and fruitful might have caused students to be satisfied, and facilitated understanding of students in the conceptual change texts group (Armagan et al., 2017).

The visual nature and cartoon characters might have triggered students' interest and subsequently facilitated their understanding of the concept more than their counterparts in the conceptual change texts group (Keogh &Naylor, 1991). The results of the study also show that both concept cartoons and conceptual change texts instructions are effective in motivating students learning (Balci et al., 2005; Ekici et al., 2007) and increasing classroom participation (Gafoor et al., 2013). Students in each experimental group were motivated to engage in series of activities that revealed their misconceptions before plausible, intelligible and fruitful explanations were presented.

Research question 3

To identify misconceptions Senior High School students, hold regarding photosynthesis, research question three was explored descriptively by comparing their initial misconceptions to those identified in the post-test in both experimental and control group. It was revealed from the results that SHS students in Ghana held misconceptions regarding photosynthesis. This finding is consistent with that of Tekkaya and Balci (2003), who were of the view that Senior High School students have several misconceptions regarding photosynthesis which make it difficult concept to conceptualize (Kurt et al., 2013; Tlala, Kabirige & Osodo, 2014; Svandova, 2013; Nas, 2010) for them to understand the concept. The results of the study show that concept cartoons and conceptual change texts are relatively effective in addressing students' misconceptions in photosynthesis as compared to the conventional method.

For instance, participant (3) in the concept cartoons group who initially had the misconception that plants obtain their food directly from the soil using their roots after the intervention recorded, "*Plants obtain their food through photosynthesis by using their chlorophyll to trap sunlight and combine it with water to synthesize complex organic food molecule*s". Participant (1) in the concept cartoons group who previously understood that the dark stage of photosynthesis is essentially the reduction of ribulose biphosphate (RuBp) to carbon dioxide, after the intervention correctly recorded, "*The dark stage of photosynthesis is simply the reduction of carbon dioxide to glucose and other organic food substances*".

Participant (2) in the conceptual change texts group who initially believed that the dark stage of photosynthesis occurs independently of the light stage wrote correctly after the intervention that, "*The dark and light stage of photosynthesis are interdependent, therefore the dark stage cannot occur in the absence of the light stage. This is because the products of the light reactions such as Adenosine Trisphosphate (ATP) and Nicotinamide Adenine Dinucleotide Phosphate NADPH which are the assimilatory power are constantly required for the dark reactions for the reduction of carbon dioxide into glucose"*. Similarly, participant (5) in the conceptual change texts group who initially had the misconception that only green plants can photosynthesize recorded after the intervention, "*Non green plants can photosynthesize because their chlorophyll may be present in less quantity and photosynthetic pigment may be masked by other pigments, therefore although they* *do not have the green color yet they can undergo photosynthesis*". These plausible and intelligible explanation on concepts related to photosynthesis revealed that students conceptual understanding had improved significantly in the conceptual change texts and concept cartoons group.

However, it was observed that students in the conventional group still held misconceptions even after the intervention. It seems misconceptions regarding photosynthesis were still strong and persistent for students in the conventional method group (Ozmen, 2007). For instance, participant (4) in the conventional method group still maintained after the intervention that plants obtained their food directly from the soil by using their roots to absorb mineral salts, whiles Participant (6) also wrote that non green plants cannot photosynthesize because they lack chlorophyll.

The finding of this study is consistent to previous studies which claim that Concept cartoons (Taslıdere, 2021; Akamca et al., 2009; Gafoor, 2013) and Conceptual change texts (Alkhawaldeh, 2019; Abdul et al., 2010; Troyer, 2011; Ozmen, 2007; Taslidere, 2021) are effective in addressing students' misconceptions in photosynthesis. The results of the study also indicates that although there are a number of misconceptions held by Senior High school students regarding photosynthesis, nonetheless, M1 (Plants prepare their food by using their roots to obtain water and mineral salts from the soil) and M3 (The dark stage of photosynthesis occurs independently of the light stage) are the strongest and frequent. Before the intervention, most of the students believed that plants obtain their energy from the soil hence did not conceptualize the process of photosynthesis as a chemical process. For instance, student (3) wrote, "*I think plants prepare their food by absorbing water and mineral salts from the soil and combine it with carbon dioxide. This is because when plants receive enough water and organic nutrients, they grow very well"*. Student (8) also answered, "*I think plants obtain their nutrients from the soil by using their roots to absorb water and mineral salts, therefore if the roots of plants are affected, the growth of plants will be affected likewise*". This finding corroborates with similar studies by Marmaroti and Galanopoulou (2006), who reported that students have misconception that plants receive their food directly from their environment hence confuse the process of photosynthesis with that of respiration. Mintzes and Wandersee (2005) also reported that most students think plants eat by using their roots to absorb nutrients from the soil.

Another common but moderate misconception was M3 in both control and experimental groups. It seems that students lack proper understanding of the biochemical nature of photosynthesis. For instance, students were of the view that the dark stage of photosynthesis occurs independently of the light stage. They considered the dark stage as a totally different reaction pathway from the light stage. Therefore, they failed to understand the complex interrelationship that exist between the two stages of photosynthesis. It seems students lacked the understanding that energy in molecular form (ATP and NADH) produced in the light stage are utilized in the dark stage to produce organic molecules hence the dark stage reaction cannot occur without the light independent stage.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary, conclusions and recommendations. Key findings, conclusions, and recommendations based on the key findings are highlighted in the summary. This chapter also points out Suggested areas for future research.

Summary

Overview of the study

This study explored the effectiveness of concept cartoons and conceptual change texts Instructional approaches on Senior High School students' understanding of concepts related to photosynthesis. Further, the study sought to explore the views of the students regarding the use of concept cartoons and Conceptual change texts Instructional approaches in the teaching and learning of concepts related to photosynthesis. Three research questions and three research hypotheses were formulated to guide the study. The embedded mixed method research design was used. Using a Multi-stage sampling technique 113 participants were selected to be part of the study. Students were administered a pre-test on concepts related to photosynthesis before the intervention to determine if they were at par in terms of their knowledge of concepts related to photosynthesis. The pre-test (two tier diagnostic) was used to determine students pre-existing conceptions about photosynthesis. The pre-existing conceptions were grouped into themes and analysed descriptively. The pre-test was also used to categorize the students into high and low achieving groups. The concept of photosynthesis was taught using conceptual change texts, concept cartoons and conventional instructional approaches to students in the three groups respectively. After each group had received the intervention, a post-test on concepts related to photosynthesis was administered to the students. A semi-structured interview was conducted with some of the students purposively selected from the concept cartoons and conceptual change texts groups to seek their views regarding the teaching approaches. Their views were recorded and transcribed.

Quantitative data was obtained from students' pre-test and post-test scores on concepts related to photosynthesis including the process of photosynthesis, adaptation of the leaf for photosynthesis, the mechanism of photosynthesis, tests for photosynthetic materials and products formed at the end of photosynthesis, and factors affecting photosynthesis. One-way analysis of variance (ANOVA), Paired-sample t-test, Independent sample t-tests and Analysis of covariance (ANCOVA) were used for the quantitative analysis. Qualitative data were obtained through interviews with selected students. The qualitative data were analyzed descriptively based on the themes generated from the opinions expressed by the students regarding the concept cartoons and conceptual change texts instructional approaches. Descriptive analysis was also used to analyse the misconceptions of students before and after the intervention.

Key findings

1. Senior High School students used for the study were at par in terms of their knowledge on concepts related to photosynthesis prior to the intervention.

2. The interventions helped in improving the knowledge of the students in concepts related to photosynthesis of the experimental groups.
3. Students in the concept cartoons, conceptual change texts and conventional groups differ in terms of their understanding of concepts related to photosynthesis. Students in the concept cartoons and conceptual change texts performed relatively better compared with those in the conventional group. No difference was found in achievement between students in concept cartoons and the conceptual change texts groups when the interventions were applied on them. `
4. Students in the high achieving group performed relatively better than their counterparts in the low achieving group in the pre-test scores. However, after the intervention, there was no statistically significant difference in the post-test scores between the high and low achieving students in the concept cartoons group and conceptual change texts group. These findings suggest that the teaching strategies were effective in bringing both high achievers and low achievers to a comparable level of understanding of photosynthesis.
5. Students had positive views about the use of concept cartoons and conceptual change texts Instructional approaches to teach concepts related to photosynthesis.
6. Students showed some misconceptions on concepts related to photosynthesis such as (1) Plants prepare their food by using their roots to obtain water and mineral salts from the soil, (2) The dark stage of photosynthesis is essentially the reduction of ribulose biphosphate (RuBp) to carbon dioxide and oxygen, (3)

The dark stage of photosynthesis occurs independently of the light stage, (4) Only green leaves can photosynthesised.

Conclusions

From the findings of this study, it can be concluded that there were significant gains in knowledge among students taught with concept cartoons conceptual change texts and conventional approaches after the intervention. This shows that the prior understanding of students of concepts related to photosynthesis improved significantly in both experimental and control groups after the intervention. The gains in knowledge by the students were influenced by the effects of the intervention and not by their prior understanding of the concepts related to photosynthesis (Delucchi, 2012).

From the study, it can also be concluded that students exposed to concept cartoons and conceptual change texts performed relatively better than their counterparts exposed to the conventional Instructional approach. This indicates that concept cartoons and conceptual change texts Instructional approaches have the potential to improve students' understanding of concepts related to photosynthesis. The findings of this study are supported by the results of the study by Ekici, Erhan and Aydin (2007) who revealed that concept cartoons was effective in improving conceptual understanding of students. Further, Esra (2013)'s findings also support this study when he reported that students' knowledge and understanding improved when taught with concept cartoons. This study is also consistent with Alkhawaldeh and Salem (2019) who indicated that students' understanding improved when taught with Conceptual change texts than their counterparts taught with the conventional

Instructional approach. Similarly, a study by Balci et al. (2006) also supports the finding from this study when it was also reported that conceptual change texts improved students' understanding of science concepts compared with the conventional Instructional approach.

The ANCOVA results indicate that the concept cartoons teaching strategies were successful in narrowing the achievement gap between high achievers and low achievers in understanding photosynthesis. The post-test scores reflect a narrowing of the gap that previously existed between these groups, which can be interpreted as a successful outcome of the teaching strategy. By addressing misconceptions, promoting cognitive engagement, providing scaffolding, and fostering an inclusive learning environment, these teaching strategies enabled students across the achievement spectrum to reach a comparable level of understanding. These findings underscore the potential of concept cartoons and conceptual change texts as effective teaching strategies for addressing educational disparities and enhancing overall student comprehension in complex scientific concepts such as photosynthesis. This positive outcome not only validates the efficacy of these teaching strategies in bridging achievement gaps but also highlights the importance of employing instructional methods that cater to the diverse learning needs of students.

Again, it can be concluded from the findings of this study that the views of students concerning the concept cartoons and the conceptual change texts instructional strategies were positive. This agrees with the results of Taslidere (2021) who reported that students were of the view that concept cartoons strategy had made them understand the concepts taught to them. Students also held that concept cartoons instruction motivated them to learn the concept of photosynthesis better than the conventional approach. This finding is supported by the study of Ekici *et al*., (2007) who showed that concept cartoons had the potential to motivate students learning. Students also revealed that the concept cartoons instruction helped them to participate in the lesson fully whiles others also declared that it was interesting and funny and helped sustained their interest throughout the intervention study. Concerning the conceptual change texts group, students held positive perceptions about the use of conceptual change texts in teaching photosynthesis. Students revealed that it had helped them understood better the concepts of photosynthesis. Students also revealed that the conceptual change texts helped them to identify their misconceptions regarding photosynthesis. This finding corroborates the findings of Abdulkadir (2017) who revealed that it improved student's understanding and helped correct their misconceptions.

Based on the findings of the study, it was indicated that students held diverse misconceptions about photosynthesis and this largely accounts for the reason why students show difficulty in understanding concepts related to photosynthesis. This study is also compactible with that of Dimec (2017), Nas (2010) and Svandova (2013) when they all reported that Senior High School students held several misconceptions regarding concepts related to photosynthesis which made it very challenging for them to fully understand the concept. Some of the misconceptions that were pointed out in this study are similar to those identified by Marmaroti *et al*. (2006) when they reported that students had the misconception that plants obtain food directly from their surroundings and those reported by Mintzes and Wandersee, (2005) when they reported that students thought plants eat by using their roots to absorb water and mineral salts from the soil.

Contributions to Knowledge and Theory, Practice and Policy:

Based on the key findings from this study, the following are the key contributions:

1. Empirical Evidence on conceptual change techniques: The study provides robust empirical evidence on the effectiveness of concept cartoons and conceptual change texts as instructional strategies. The findings reveal that both concept cartoons and conceptual change texts significantly improved students' understanding of photosynthesis concepts compared to conventional teaching methods. This underscores the potential of these tools in addressing students' misconceptions and enhancing conceptual clarity in science education.

2. Bridging the Achievement Gap: One of the most notable contributions of this research is the demonstration of how concept cartoons and conceptual change texts can effectively bridge the achievement gap between high and low achievers. The study showed that, while there were significant differences between high and low achievers in the pre-test scores, the post-test scores revealed no statistically significant differences between these groups after the intervention. This suggests that these teaching strategies not only improved overall student understanding but also promoted equity in learning outcomes, making these strategies particularly valuable for diverse classrooms.

Recommendations

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

1. Senior High schools Biology teachers may employ concept cartoons and conceptual change texts as part of their instructional strategies to help overcome students' difficulties in understanding biology concepts.
2. Biology curriculum developers may recommend concept cartoons and Conceptual change texts instructional strategy as examples of constructivist teaching approaches that teachers may use to teach difficult biology concepts.
3. The MoE and GES should organize refresher courses, workshops and seminars for biology teachers on how to use conceptual change texts and concept cartoons teaching approaches to teach concepts in Senior High School Biology.

Suggestions for Further Research

The study explored the effect of concept cartoons and conceptual change texts on Senior High School students' understanding of photosynthesis. However, this study did not consider how they could be integrated with other useful teaching approaches. In view of this, it is suggested that further study explore how these teaching approaches could be integrated with other helpful teaching models. For instance, concept cartoons could be integrated with the 7 E's teaching model whiles conceptual change texts could be integrated with the REACT teaching model.

This research did not consider how computer could be used to develop the concept cartoons and conceptual change texts instructions. In view of this, it is recommended that further studies should be done on how computer assisted concept cartoons and conceptual change texts could be used to improve students' understanding. Future studies could be conducted using other conceptual change models apart from those used in this study. Further studies could also be done using the same teaching approaches used in this study but with different challenging concepts such as respiration or genetics.

Further studies could investigate the long-term impact of concept cartoons and conceptual change texts on students' retention of knowledge. a longitudinal approach would help to determine whether the conceptual change achieved through these interventions is sustained over time.

REFERENCES

Abdul, G. K., & Akhilesh, P.T. (2010). Strategies for facilitating conceptual change in school physics. *Innovations and Research in Education*, *3*(1), 34-42.

Abdul, R. M., Akkus, S. (2010). Effectiveness of instruction based on the constructivist approach on understanding chemical equilibrium concepts. *Research in Science & Technological Education*, *21*(2), 209-227.

Abdulkadir, U. (2018). Conceptual teaching based on scientific storyline method and Conceptual change texts: Latitude-parallel concepts. *International Journal of Higher Education, 7*(1), 323-325.

Adu-Gyamfi, K. (2014). Challenges faced by science teachers in the teaching of integrated science in Ghanaian Senior High Schools in Ghana. *Journal of Science and Mathematics Education*, *6*(2), 59-80.

Agiande, D. U., Williams, J. J., & Dunnamah, A. Y. (2015). Conceptual change theory as a teaching strategy in environmental education. *European Scientific Journal*, *11*(35), 395-399.

Akamca, G. O., Ellez, A. M., & Hamurcu, H. (2009). Effects of computer aided concept cartoons on learning outcomes. *Procedia Social and Behavioral Sciences*, *2*(3), 296-301.

Alkhawaldeh, A., & Salem, A. (2019). The comparative effects of cyclic inquiry model, conceptual change text, and traditional instruction on students' understanding of photosynthesis and respiration in plants. *Journal of International Education and Practice, 2*(1), 1-18. https://doi.org/10.30564/jiep.v2i1.335

Amir, R., & Tamir, P. (1994). In-depth analysis of misconceptions as a basis for developing research-based remedial instruction: The case of photosynthesis. *American Biology Teacher*, *3*(56), 94-100.

Amponsah, D. K., & Ochonogor, C. E. (2018). Facilitating conceptual change in Students' comprehension of electrochemistry concepts through collaborative teaching strategy. *American Journal of Educational Research*, *6*(6), 596-601.

Armagan, O. F., Melike, O. K., & Akin, B. S. (2017). Effectiveness of conceptual change texts: A metaanalysis. *European Journal of Science and Mathematics Education*, *5*(4), 343-354.

Bada, S. O., & Olusegun, S. (2015). Constructivism learning theory: A paradigm for teaching and learning. *Journal of Research & Method in Education*, *5*(6), 66-70.

Balci, S., Cakirogu. J. & Tekkaya C. (2006). Engagement, exploration, extension, and evaluation (5E) learning cycle and conceptual change texts as learning tools. *Journal of Biochemistry and Molecular Biology Education*, *34*(3), 199-203.

Balim, G. A., Inel, D., & Evrekli, E. (2008). The effect of concept cartoons on science student's academic achievement and enquiry learning skill perceptions. *Elementary Education Online*, *7*(1), 188-202.

Barrutia, O., & Diez, J. R. (2019). 7 to 13-year-old students' conceptual understanding of plant nutrition: Should we be concerned about elementary teachers' instruction? *Journal of Biological Education*, *4*(6), 22-24.

Braach, J. L., Goldman, S. R., & Wiley, J. (2013). The influences of text and reader characteristics on learning from refutations in science texts. *Journal of Educational Psychology*, *100*, 291-309.

Cakir, M. (2008). Constructivist approaches to learning in science and their implications for science pedagogy: A literature review. *International Journal of Environmental Science*, *3*(4), 193-206.

Cakir, O. S., Geban, O., & Yuruk, N. (2002). Effectiveness of conceptual change text-oriented instruction on students' understanding of cellular respiration concepts. *Biochemistry and Molecular Biology Education*, *30*(4), 239-243.

Carey, S. (1985). *Conceptual change in childhood*. Cambridge, MA: MIT Press.

Cepni, S., & Emine, Ç. (2010). Using a conceptual change text as a tool to teach the nature of science in an explicit reflective approach. *Asia-Pacific Forum on Science Learning and Teaching*, *11*(10), 1-29.

Cetin-Dindar, A. (2016). Student motivation in constructivist learning environment. *Learning Environments Research*, 19, 163-181. https://doi.org/10.1007/s10984-015-9202-5

Chen, Y. T., & Wang, J. H. (2016). Analyzing with Posner's conceptual change model and Toulmin's model of argumentative demonstration in senior high School students' mathematic learning. *International Journal of Information and Education Technology*, *6*(6), 232-243.

Chi, M. T. H. (1992). Conceptual change in and across ontological categories: Examples from learning and discovery in science. In R. Giere & H. Feigl (eds.), *Cognitive Models of Science* (pp. 129-186). Minneapolis: University of Minnesota Press.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education* (6th ed.). Routledge.

Cohen, L., Manion, L., & Morrison, K. (2017). *Research methods in education* (8th ed.). Oxford, UK: Routledge.

Cokadar, H. (2012). Photosynthesis and respiration processes: Prospective teachers' conception levels. *Education and Science*, *37*(164), 81-93.

Creswell, J. W., & Clark, V. P. (2012). *Designing and conducting mixed methods research* (3rd ed.). California, USA: SAGE Publications.

Delucchi, M. (2014). Measuring students' learning in social statistics: A pre-test-post-test study of knowledge gain in teaching sociology. *Teaching Sociology*, *42*(3), 231-239.

Diakidoy, I. A. N., Kendeou, P., & Ioannides, C. (2003). Reading about energy: The effects of text design on students' conceptual understanding and learning in science. *Science Education*, *87*(1), 72-98. https://doi.org/10.1002/sce.10008

Dimec, D. (2017). Scientific conceptions of photosynthesis among primary school pupils and student teachers of biology. *Journal of Baltic Science Education*, *13*(2), 49-68.

Dimec, D., & Strgar, J. (2017). The effect of inquiry-based learning approach on students' performance in photosynthesis. *Journal of Biological Education*, *51*(4), 311-319. https://doi.org/10.1080/00219266.2017.1364215

Driver, R., & Tiberghien, A. (1985). Children’s ideas in science. Open University Press.

Duit, R., & Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education*, *25*(6), 671-688.

Ekici, F., Erhan, E. & Aydin, F. (2007). Utility of concept cartoons in diagnosing and overcoming misconceptions related to Photosynthesis. *International Journal of Environmental and Science Education*, *2*(4), 111-124.

Esra, H., Yilmaz, Z., & Tekin, A. (2013). The impact of educational interventions on student learning outcomes. *Educational Research Review, 28*(2), 150-167.

Esra, K. (2013). Effects of cartoons on students’ achievement and attitude in Biology (Endocrine system). *Kastamonu Education Jounal, 21*(3), 931-944.

Esra, K., & Ponar, K. (2010). Determination of student misconceptions in photosynthesis and respiration unit and correcting them with the help of cai material. *Procedia Social and Behavioral Sciences*, *2*(3), 111-3118.

Gafoor, K. A., & Shilna, V. (2013, December 5–6). *Role of concept cartoons in chemistry learning*. Learning Science by Doing – Sciencing, Madampam, India, 25-89.

Guzzetti, B. J., Snyder, T. E., Glass, G. V., & Gamas, W. S. (1993). Promoting conceptual change in science: A comparative meta-analysis of instructional interventions. *Journal of Research in Science Teaching*, 30(2), 187-203. https://doi.org/10.1002/tea.3660300204

Hanson, W. E., Creswell, J. W., Clark, P. L., Petska, K. S. & Cresswell, D. J. (2005). Mixed methods research designs in counselling psychology. *Journal of Counselling Psychology*, *52*(2), 224-235.

Haslam, F., & Treagust, D. (1987). Diagnosing secondary students' misconceptions of photosynthesis and respiration in plants using a two-tier multiple-choice instrument. *Journal of Biological Education*, *21*(3), 124-145.

Hewson, P. W. (1981). A Conceptual change approach to learning science. *European Journal of Science Education*, 3(4), 383-396.

Hewson, P. W. (1982). A case study of conceptual change in special relativity: The influence of prior knowledge in learning. *European Journal of Science Education*, *4*(1), 61-78.

Hewson, P. W., & Hamlyn, D. (1984). The Role of conceptual change texts in facilitating conceptual change. *Cognition and Instruction*, *1*(4), 289-333.

Kabapinar, F. (2005). Effectiveness of teaching via concept cartoons from the point of view of constructivist approach. *Educational Sciences: Theory and Practices*, *5*(1), 135-146.

Keogh, B., & Naylor, S. (1991). Concept cartoons: A new way to teach science concepts. *School Science Review*, 72(258), 33-36.

Keogh, B., & Naylor, S. (1999). Concept cartoons, teaching and learning in science: An evaluation. *International Journal of Science Education*, *21*(4), 431-446.

Keogh, B., & Naylor, S. (1999). Concept cartoons: Stimulating discussion and thinking in science. *Primary Science Review*, *58*(8), 14-16.

Keogh, B., Naylor, S., & Wilson, C. (1998). Concept cartoons: A strategy to promote discussion in science lessons. *International Journal of Science Education*, 20(2), 131-146.

Koba, S., & Tweed, A. (2009). *Hard-to-teach biology concepts: A framework to deepen student understanding*. Virginia, USA: National Science Teachers Association Press.

Kocdar, S., Karadag, N., & Murat, D. S. (2016). Analysis of the difficulty and discrimination indices of multiple-choice questions according to conceptual levels in open and distance learning content. *Turkey online Journal of Education Technology*, *15*(4), 16-24.

Kose, S. (2008). Diagnosing student misconceptions: Using drawings as a research method. *World Applied Sciences Journal*, *3*(2), 283-293.

Kose, S., & Uşak, M. (2006). Determination of prospective science teachers' misconceptions: Photosynthesis and respiration in plants. *International Journal of Environmental and Science Education*, *3*(1), 25-52.

Kuhn, T. (1962). *The structure of scientific revolution*. Chicago, USA: University of Chicago Press.

Kurt, H., Gulay, E., Akta M., & Aksu, O. (2013). The concept of photosynthesis which is an indicator of life in plants: A cognitive structure study. *American-Eurasian Journal of Agricultural & Environmental Science*, *13*(9), 1207-1231.

Lewis, J. (2009). Can theoretical constructs in science be generalised across disciplines? *Journal of Biological Education*, *44*(1), 5-11.

Liu, S. H.-J., & Lan, Y. J. (2016). Social constructivist approach to web-based EFL learning: Collaboration, motivation, and perception on the use of Google Documents. *Journal of Educational Technology & Society*, *19*(1), 171-186.

Marmaroti, P., & Galanopoulou, D. (2006). Pupils' understanding of photosynthesis: A questionnaire for the simultaneous assessment of all aspects. *International Journal of Science education*, *28*, 383-403.

Mason, L. (2001). Teaching science concepts through a conceptual change text. *Journal of Science Education*, 85(6), 623-644. https://doi.org/10.1002/sce.1030

Mikkila-Erdmann, M. (2001). Improving conceptual change concerning photosynthesis through text design. *Journal of Learning and Instruction*, *11*(3), 241-257. https://doi.org/10.1016/S0959-4752(00)00040-4

Miles, R. (2015). Tutorial instruction in science education. *Cypriot Journal of Educational Science*, *10*(2), 168-17.

Mintzes, J. J., & Wandersee, J. H. (2005). Research in science teaching and learning: A human constructivist view. In J. J. Mintzes, J. H. Wandersee, & J. D. Novak (eds.), *Teaching science for understanding: A human constructivist view* (pp. 59-92). California, USA: Academic Press.

Morrison, J. A., Raab, F. J., & Ingram, M. (2008). Exploring the role of concept cartoons in enhancing student learning in primary science. *International Journal of Science Education*, 30(11), 1375-1398. https://doi.org/10.1080/09500690701537071

Nadelson, L.S., Heddy, B.C., Jones, S., T. & Johnson, M. (2018). Conceptual change in science teaching and learning: Introducing the dynamic model of conceptual change. *International Journal of Educational Psychology*, *7*(2), 151-195.

Nas, H. (2010). Teaching photosynthesis in a compulsory school context: Students' reasoning, understanding and interactions. *International Journal of Science Education*, 28(5), 49-63.

Naylor, S., & Keogh, B. (2013). Concept cartoons: What have we learnt? *Science Education*, 97(4), 549-580. https://doi.org/10.1002/sce.21065

Nkechinyere, A. E., & Arokoyu A. A. (2018). Teaching strategies on biology achievement of secondary school students with different learning styles in Rivers State, Nigeria. *International Journal of Multidisciplinary Research and Development*, *5*(4), 82-88.

Okoli, J. N. & Azubuike, E. N. (2012). Effect of peer tutoring instructional strategy on achievement in biology by Senior High School slow learners in Nigeria. *Asia Academic Research Journal of Multidisciplinary*, *16*(1), 547-563.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, 25(9), 1049-1079. https://doi.org/10.1080/0950069032000032199

Ozay, E., & Oztas, H. (2003). Secondary students' interpretations of photosynthesis and plant nutrition. *Journal of Biological Education*, 37(2), 68-70. https://doi.org/10.1080/00219266.2003.9655852

Ozdemir, G., & Clark, D. B. (2007). Knowledge structure coherence in conceptual change: comparing multiple conceptual representations and changes in the domain of genetics. *Science Education*, *91*(3), 490-511.

Ozmen, H. (2007). The effectiveness of conceptual change texts in remediating High School students' alternative conception concerning chemical equilibrium. *Asia Pacific Education Review*, *3*(8), 413-425.

Pallant, J. (2007). *SPSS survival manual: A step by step guide to data analysis using SPSS program* (6th ed.). London, UK: Mcgraw-hill education.

Parker, J. M., Merrill, J., Merritt, B., Richmond, G., & Urban-Lurain, M. (2012). Exploring undergraduates' understanding of photosynthesis using diagnostic question clusters. *CBE Life Science Education*, *11*(1), 47-57.

Perales, F. J., & Vilchez, J. M. (2005). The teaching of physics and cartoons: Can they be interrelated in secondary education? *International Journal of Science Education*, *27*(14), 1647-1670.

Pintrich, P. R.,Marx, R.W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research*, *6*, 167-199.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Towards a theory of conceptual change. *Journal of Science Education*, *2*(66), 211-227.

Quainoo, A. B., Otami, D. C. & Owusu, K. A. (2021). Effect of the REACT strategy on senior high students' achievement in molecular genetics. *Lumat: International Journal on Math, Science and Technology Education*, *9*(1), 696-716.

Ray, D., Beardsley, L., & Feldman, A. (2008). Student misconceptions in biology and their effects on learning. *Journal of Science Education and Technology*, *17*(3), 219-231. https://doi.org/10.1007/s10956-007-9053-9

Ray, M. A., & Beardsley P. M. (2008). Overcoming student misconceptions about photosynthesis: A model and inquiry-based approach using aquatic plants. *Routledge*, *45*(1), 13-22.

Roya, R. J., & Davatgari, H. (2015). Review of constructivism and social constructivism. *Journal of Social Sciences, Literature and Languages*, *1*(1), 9-16.

Russel, A. W., Netherwood, G. M. A., & Robinson, S. A. (2004). Photosynthesis in Silico: Overcoming the challenges of photosynthesis using a multimedia CD-ROM. *Bioscience Education*, *3*(1), 1-14.

Sarpah, I. (2021). Improving the conceptual understanding of the process of photosynthesis to second year science students of Abetifi Presbyterian senior high school: The use of the model of the leaf and Animat. Retrieved from https://afribary.com/works.

Simatwa, E. M. W. (2010). Piaget's theory of intellectual development and its implication for instructional management at presecondary school level. *Educational Research and Reviews*, *5*(7), 366-371.

Sodervik, I., Mikkilä-Erdmann, M., & Vilppu, H. (2014). Promoting the learning of the photosynthesis concept: A case study of conceptual change in primary school teacher education. *Research in Science Education*, *44*(6), 841-859.

Stephenson, P., & Warwick, P. (2002). Using concept cartoons to support progression in students' understanding of light. *Physics Education Journal*, *37*(2), 135-140.

Svandova, K. (2013). Lower secondary school pupils' misconceptions about photosynthesis and plant respiration: Pilot study. *Creativity and Innovation in Educational Research*, *2*(3), 22-27.

Taslidere, E. (2021). Relative effectiveness of conceptual change texts with concept cartoons and 5E learning model with simulation activities on pre-service teachers' conceptual understanding of waves. *Participatory Educational Research*, *8*(4), 215-238.

Tekkaya, C., & Balci, S. (2003). Determination of students' misconceptions concerning photosynthesis and respiration in plants. *Haccettepe University Journal of Education*, 24, 101-107.

Tlala, B., Kabirige, I., & Osodo, J. (2014). Investigating grade 10 learners' achievements in photosynthesis using conceptual change model. *Journal of Baltic Science Education*, *13* (2), 155-164.

Treagust, D., Duit, R., & Widodo, R. (2008). Teaching science for conceptual change: Theory and practice. *International handbook of Science Education, 3*(4), 3-25.

Troyer, J. A. (2011). Conceptual change instructions: A method for facilitating consciousness in problem solving activities. *Procedia-Social and Behavioural Sciences*, *2*(9), 33-38.

Tuera, S. (2019). Effect of instruction based on conceptual change activities on students' understanding of static biology concepts. *Research in Science & Technological Education*, 25(2), 243 – 267.

Vosniadou, S., Vamvakoussi, X., & Skopeliti, I. (2008). The framework theory approach to the problem of conceptual change. In S. Vosniadou (ed.), *International handbook of research on conceptual change*, (pp. 3-34). New York, USA: Routledge.

Wandersee, J. H., & Mintzes, J. J. (2005). Misconceptions in biology. *Handbook of Research on Science Teaching and Learning* (pp. 177-210). National Science Teachers Association.

West African Examinations Council (2014). *Chief Examiner's Report. West African Senior Secondary Certificate Examination*. *Biology*. Accra: Author

West African Examinations Council (2015). *Chief Examiner's Report. West African Senior Secondary Certificate Examination*. *Biology.* Accra: Author

West African Examinations Council (2016). *Chief Examiner's Report. West African Senior Secondary Certificate Examination*. *Biology.* Accra: Author

West African Examinations Council (2017). *Chief Examiner's Report. West African Senior Secondary Certificate Examination*. *Biology.* Accra: Author

Yuruk, N., & Geban, O. (2001). Conceptual change text: A supplementary material to facilitate conceptual change in electrochemical cell concepts. *Journal of Educational Research, 45*(3), 123-135.

Zembylas, M. (2005). Three perspectives on linking the cognitive and the emotional in science learning: Conceptual change, socio-constructivism and poststructuralism. *Studies in Science Education, 41*(1), 91-116.

APPENDICES

APPENDIX A

ACHIVEMENT TEST

A Test on Photosynthesis

Choose from the options lettered A to D the one that best answers the questions and give your reason in the blank space provided.

Duration: 40 minutes

SEX……………..AGE……….

1. Plants obtain their food by ……………………………………
   A. absorbing carbon-dioxide and water in the presence of sunlight
   B. taking in carbon-dioxide and oxygen from the environment
   C. taking carbon-dioxide and chlorophyll from the environment
   D. using their roots to absorb water and mineral salts from the soil
   THE REASON FOR MY ANSWER IS
   ………………………………………………………………………
2. Which of the following are factors affecting the dark stage of photosynthesis?
   i. Water
   ii. CO_2
   iii. NADPH
   iv. ATP
   A. i and ii only
   B. ii, iii and iv
   C. ii and iii only
   D. i, ii, iii and iv
   THE REASON FOR MY ANSWER IS
   ………………………………………………………………………
3. During an experiment, a variegated leaf was exposed to sunlight for a few hours and later tested for starch. Which of the following conditions of photosynthesis is likely to be tested for?

A. Carbon dioxide
B. Chlorophyll
C. Sunlight
D. Water

THE REASON FOR MY ANSWER IS

………………………………………………………………………

4. All the following affects the rate of photosynthesis **EXCEPT………..**
   A. Carbon dioxide concentration
   B. Oxygen concentration
   C. Chlorophyll concentration
   D. Temperature

   THE REASON FOR MY ANSWER IS

   ………………………………………………………………………

5. The light dependent stage of photosynthesis occurs in the…………………………
   A. Palisade
   B. Granum
   C. Stroma
   D. Thylakoid membrane

   THE REASON FOR MY ANSWER IS

   …………………………………………………………………………

   The chemical process in which a phosphate group is added to an organic molecule is called…………………..

A. Photolysis
B. Photosynthesis
C. Phosphorylation
D. Phospholysis

THE REASON FOR MY ANSWER IS

………………………………………………………………………

6. Which of the following is **Not Correct** concerning the *Light stage* of photosynthesis?
   A. ATP is the source of energy for the light stage
   B. Both photolysis and phosphorylation occurs
   C. Light energy cause the combination of inorganic phosphorus(pi) and ADP to form ATP
   D. The hydrogen ions are converted into hydrogen atoms which is used to reduce NADP to NADPH

   THE REASON FOR MY ANSWER IS

   ……………………………………………………………………
7. Apart from gases required for photosynthesis, the plant also uses Oxygen at night for…………………………
   A. Excretion
   B. Movement
   C. Photosynthesis
   D. Respiration

   THE REASON FOR MY ANSWER IS………………………………
8. Air that enters the leaf for photosynthesis is stored in the………
   A. Stomata
   B. Spongy mesophyll
   C. Vascular tissues
   D. Vacuole

   THE REASON FOR MY ANSWER IS

   ………………………………………………………………………….
9. Excessive sugar after photosynthesis is stored as ………………………
   A. Galactose
   B. Glycogen
   C. Maltose
   D. Starch

   THE REASON FOR MY ANSWER IS

   ……………………………………………………………………………

10. The light independent stage of photosynthesis occurs in the ……………………………..
    A. Palisade
    B. Granum
    C. Stroma
    D. Thylakoid membrane

    THE REASON FOR MY ANSWER IS

    ………………………………………………………………………………

11. What biological process is illustrated by the equation

    2H2O ⟶ $4H^{+}$ +02+4e-

    A. Dehydrogenation of water
    B. Phosphorylation of water
    C. Dehydration of water
    D. Photolysis of water

    THE REASON FOR MY ANSWER IS

    ………………………………………………………………………………

12. The light stage of photosynthesis is **not** affected by ………………………………..
    A. availability of water
    B. availability of NADP
    C. temperature
    D. light intensity

    THE REASON FOR MY ANSWER IS

    …………………………………………………………………………

13. The tissue which manufactures carbohydrate in the leaves is……………
    A. Endodermis
    B. Epidermis
    C. Hypodermis
    D. Palisade

    THE REASON FOR MY ANSWER IS

    ………………………………………………………………………………

14. A chemical test carried out on leaves to determine the product of photosynthesis is known as………………………..
    A. Benedict's test
    B. Biuret Test
    C. Iodine Test
    D. Lime water test

    THE REASON FOR MY ANSWER IS

    ……………………………………………………………………
15. Which of the following compound in the *light stage of photosynthesis* is needed in the *Dark stage?*
    A. ADP
    B. Hydroxyl ion
    C. NADPH2
    D. Oxygen

    THE REASON FOR MY ANSWER IS

    ……………………………………………………………………
16. Boiling a leaf when testing for starch is essential for…………………………………
    A. decolourising the leaf
    B. kill the cells and inactivate the enzymes
    C. provide the right temperature
    D. soften the leaf

    THE REASON FOR MY ANSWER IS

    ……………………………………………………………………
17. Which of the following is **Correct** about photosynthesis?
    A. The rate of photosynthesis increases with increasing in light intensity
    B. The rate of photosynthesis is increased at lower temperature
    C. The lower the carbon dioxide concentration, the higher the rate of photosynthesis
    D. Chlorophyll concentration does not affects the rate of photosynthesis

    THE REASON FOR MY ANSWER IS

……………………………………………………………………

18. The three main regions of the leaf are …………………………………

    A. Epidermis, Hypodermis and Vascular tissues
    B. Epidermis, Mesophyll and Vascular tissues
    C. Vascular tissues, Mesophyll and Stomata
    D. Vascular tissues, Mesophyll and Vascular tissues.

    THE REASON FOR MY ANSWER IS

    ……………………………………………………………………

19. The two major processes of *light stage* of photosynthesis are ……………..

    A. carboxylation and phosphorylation
    B. Phosphorylation and photolysis
    C. Photolysis and Hydrogenation
    D. Carboxylation and photolysis

    THE REASON FOR MY ANSWER IS

    ……………………………………………………………………

20. Essentially, the *dark stage reaction* involves the reduction of

    A. Carbon dioxide to form glucose
    B. Glucose to form carbon dioxide and oxygen
    C. Light to form glucose and carbon dioxide
    D. Water and carbon dioxide to form ATP

    THE REASON FOR MY ANSWER IS

    ……………………………………………………………………

21. All the following are fate of the product of photosynthesis **EXCEPT………**

    A. production of cellulose to build cell wall
    B. respiration to release energy
    C. Storage as fatty acids and glycerol
    D. Synthesizing proteins and lipids

    THE REASON FOR MY ANSWER IS

    ……………………………………………………………………

22. Which of the following is an adaptation of the leaf for photosynthesis?

    A. Cell wall and cell membrane are freely permeable to carbon dioxide and water
    B. It is thick enabling oxygen to diffuse easily to the mesophyll cells
    C. It has small flat shape giving it a small surface area to absorb sunlight and water.
    D. Presence of stomata only on the upper surface to reduce rate of transpiration

    THE REASON FOR MY ANSWER IS

    …………………………………………………………………………

23. The best time to pluck a leaf for experiment is……………………………..

    A. After being exposed to sunlight
    B. Before the sun rise
    C. Six hours after sunset
    D. Three hours after the sunset

    THE REASON FOR MY ANSWER IS

    …………………………………………………………………………

24. The Limiting factors of photosynthesis are……………………………….

    A. Carbon dioxide concentration, temperature and light intensity
    B. Oxygen concentration, temperature and light intensity
    C. Pollution, carbon dioxide concentration and temperature
    D. Water, Chlorophyll and enzymes

    THE REASON FOR MY ANSWER IS

    ………………………………………………………………………

APPENDIX B

ANSWERS, DIFFICULTY AND DISCRIMINATION INDICES FOR ITEMS ON THE ACHIEVEMENT TEST

TEST ITEMS	CORRECT RESPONSE	NUMBER OF UPPER GROUP(RU)	NUMBER OF LOWER GROUP(RL)	DIFFICULT INDEX(*P*)	DISCRIMINATION INDEX(*D*)
1.	D	12	7	0.7	0.4
2.	B	07	1	0.3	0.5
3.	C	13	6	0.7	0.5
4.	D	07	0	0.3	0.5
5.	B	0	0	0.0	0.0
6.	C	6	0	0.2	0.5
7.	C	3	3	0.2	0.0
8.	C	7	0	0.3	0.5
9.	B	2	1	0.1	0.1
10.	C	6	2	0.3	0.3
11.	C	4	3	0.3	0.1
12.	C	2	1	0.1	0.1
13.	D	1	5	0.2	-0.3
14.	D	7	4	0.4	0.2
15.	C	6	4	0.4	0.2
16.	B	7	0	0.3	0.5
17.	C	9	5	0.5	0.3
18.	A	4	1	0.2	0.2
19.	B	8	2	0.4	0.5
20.	C	1	1	0.1	0.0
21.	A	3	1	0.2	0.2
22.	D	10	2	0.5	0.6
23.	C	3	3	0.2	0.0
24.	A	9	2	0.4	0.5
25.	A	7	4	0.4	0.2

APPENDIX C

ITEM DISTRACTOR ANALYSIS

ITEMS	GROUPS	RESPONSES				
		A	B	C	$D^{\times}$	Omitted
1.	Upper group	1	0	0	12	0
	Lower group	4	1	1	07	0
		A	$B^{\times}$	C	D	Omitted
2	Upper group	3	7	1	1	1
	Lower group	4	1	3	4	
		A	B	$C^{\times}$	D	Omitted
3	Upper group	0	0	13	0	0
	Lower group	1	2	6	4	0
4		A	B	C	$D^{\times}$	Omitted
	Upper group	1	2	2	7	
	Lower group	3	0	8	0	1 2
5		A	$B^{\times}$	C	D	Omitted
	Upper group	2	0	3	8	0
	Lower group	1	0	2	10	0
6		A	B	$C^{\times}$	D	Omitted
	Upper group	1	0	6	6	0

	Lower group	3	1	0	8	1
7		A×	B	C	D	Omitted
	Upper group	3	0	1	7	2
	Lower group	3	2	2	6	0
8		A	B	C×	D	Omitted
	Upper group	3	1	7	1	1
	Lower group	5	2	0	6	0
9		A	B×	C	D	Omitted
	Upper group	7	2	2	1	1
	Lower group	3	1	6	2	1
10		A	B	C×	D	Omitted
	Upper group	1	3	6	3	0
	Lower group	1	3	2	6	1
11		A	B	C×	D	Omitted
	Upper group	3	2	4	3	1
	Lower group	4	0	3	4	2
12		A	B	C×	D	Omitted
	Upper group	1	8	2	2	0
		2	7	1	1	1

	Lower group					
13		A	B	C	D$^{\times}$	Omitted
	Upper group	4	0	7	1	1
	Lower group	3	1	4	5	0
14		A	B	C	D$^{\times}$	Omitted
	Upper group	5	1	0	7	0
	Lower group	4	3	2	4	0
15		A	B	C$^{\times}$	D	Omitted
	Upper group	4	3	6	0	0
	Lower group	3	3	4	0	3
16		A	B$^{\times}$	C	D	Omitted
	Upper group	2	7	2	2	0
	Lower group	0	1	5	4	3
17		A	B	C$^{\times}$	D	Omitted
	Upper group	3	1	9	0	0
	Lower group	4	3	5	1	0
18		A$^{\times}$	B	C	D	Omitted
	Upper group	4	2	4	3	0

	Lower group	1	3	3	4	2
19		A	B×	C	D	Omitted
	Upper group		8			
	Lower group	1	2	4	2	4
20		A	B	C×	D	Omitted
	Upper group	3	4	1	3	2
	Lower group	2	3	1	4	3
21		A×	B	C	D	Omitted
	Upper group	3	2	3	3	2
	Lower group	1	2	4	3	3
22		A	B	C	D×	Omitted
	Upper group	0	2	1	10	0
	Lower group	3	3	3	2	2
23		A	B	C×	D	Omitted
	Upper group	3	2	3	3	2
	Lower group	1	3	3	2	4
24		A×	B	C	D	Omitted
	Upper group	9	2	2	0	0
		2	1	8	1	1

	Lower group					
25		$A^{\times}$	B	C	D	Omitted
	Upper group	7	3	0	3	0
	Lower group	4	1	5	1	2

APPENDIX D

CONCEPTUAL CHANGE TEXT LESSON

WEEK ONE (1)

STEP 1

Many people believe that plants eat by using their roots because all the essential nutrients required for plant growth are absorbed from the soil and transported to all other parts of the plant. State with reasons whether you consider photosynthesis as a process whereby plants obtain water and mineral salts from the soil? Write your answer in the blank space provided.

ANSWER…………………………………………………………………………

……………………………………………………………………………………

STEP 2

The table shows common misconceptions and the reasons of these misconceptions form.

WRONG IDEAS
5. Plants eat by using their roots because all the essential nutrients required for plant growth are absorbed from the soil and transported to all other parts of the plant.
6. The raw materials for photosynthesis are water and mineral salts because these are the most important materials for plant survival
7. Photosynthesis is important because it provides food for plants survival
8. Non green plants like fungi which do not contain chlorophyll or similar pigment can also photosynthesize because they all have roots for absorbing nutrients from the soil.
9. Photosynthesis can occur at every time of the day. This is because the plant constantly takes in carbon dioxide.

These views are wrong scientifically

STEP 3.

Right ideas

6. Plants obtain their energy by making carbohydrate from carbon-dioxide and water in the presence of chlorophyll using energy captured from sunlight.
7. The raw materials for photosynthesis are water (H20) and carbon-dioxide (C02) and the energy required to drive this anabolic process is sunlight absorbed by chlorophyll.

The overall reaction involved in photosynthesis is:

$6Co2+6H20 \longrightarrow C6H12O6+602.$

8. Photosynthesis is important not because it provides plants with food but also sustains all life on earth.
9. Non green plants such as fungi do not contain chlorophyll or photosynthetic pigment hence cannot undergo photosynthesis. However, some non-green plants such as brown and red algae can undergo photosynthesis because they have photosynthetic pigment which is mask by brown and red color respectively.
10. Photosynthesis can only occur during the day when sunlight is available. During the night, photosynthesis ceases and respiration takes place resulting in the release of oxygen.

STEP 4.

Reading Texts for photosynthesis, week one:

STEP 5

Answer the following questions

7. Define photosynthesis

…………………………………………………………………………………

8. State two importance of photosynthesis

…………………………………………………………………………………

9. Write a balance chemical equation for photosynthesis

…………………………………………………………………………………

WEEK TWO (2)

STEP 1

Most young people believe that the main photosynthetic organ is the root because the root absorbs all the essential nutrients for photosynthesis to take place. Do you agree with this conception? Explain your answer whether you agree or not in the blank space provided.

ANSWER……………………………………………………………………

STEP 2

The table shows common misconceptions and the reasons of these misconceptions form.

WRONG IDEAS
1. Every part of the plant that is exposed to sunlight, water and carbon dioxide can photosynthesize because they are all contain special features that enable them to undergo photosynthesis
2. The leaves of plants undergo photosynthesis because they are numerous and are held upright to receive direct sunlight.
3. Only green leaves can undergo photosynthesis because non green leaves do not contain chlorophyll.

These views are wrong scientifically

STEP 3.

Right ideas:

1. Only the leaves and some green stem can undergo photosynthesis because only some green stem of some plants and the leaves contain chloroplast. The root cannot undergo photosynthesis because they do not contain chloroplast and do not receive sunlight.

2. The leaves of plants undergo photosynthesis because of their special adaptations and not because they are numerous on the plant and are held upright.
3. Some leaves contain chlorophyll that are masked by different pigments such as red and brown and as such can undergo photosynthesize.

STEP 4.

Reading Texts: Texts on photosynthesis for week two

STEP 5

Answer the following questions

1. Explain how the leaf is adapted for photosynthesis

…………………………………………………………………………………

2. Describe the longitudinal section of the leaf

…………………………………………………………………………………

WEEK THREE (3)

STEP 1

The main product formed after photosynthesis is glucose and oxygen and these are used by the plants themselves. Occasionally, they produce carbon dioxide after photosynthesis which are released into the environment as by product. Explain with reason whether this idea is right or wrong.

ANSWER………………………………………………………………………

STEP 2

The table shows common misconceptions and the reasons of these misconceptions form.

WRONG IDEAS
1. Carbon dioxide is a by- product of photosynthesis because plants respire during photosynthesis and bring out excess carbon dioxide
2. Plants produce starch and water after photosynthesis this is because both starch and water are stored in many parts of the plants.

These views are wrong scientifically

STEP 3.

Right ideas

1. Oxygen is the gas produced after respiration. Plants take in carbon dioxide during photosynthesis and bring out oxygen after photosynthesis
2. Glucose is the organic compound formed after photosynthesis but excess glucose is converted and stored as starch in the plant.

STEP 4.

Reading Texts: Texts for photosynthesis for week 3.

STEP 5

Answer the following questions

1. What is the main product formed after photosynthesis

……………………………………………………………………………………

2. Describe the fate of the product of photosynthesis

……………………………………………………………………………………

WEEK FOUR (4)

STEP 1

Some people do not perceive starch and oxygen as the products formed after photosynthesis. How can you proof to your class one sister that starch and oxygen are produced after photosynthesis.

ANSWER……………………………………………………………………

STEP 2

The table shows common misconceptions and the reasons of these misconceptions form.

WRONG IDEAS
1. In testing for starch in a leaf, the leaf is boiled in water to remove the chlorophyll. This is because the water absorbs the chlorophyll pigments and make it transparent.
2. In testing for starch, iodine solution gives a purple or violet color.
3. In testing for the presence of oxygen, NaHCO3 is added to the set up to produce more oxygen.

These views are wrong scientifically

STEP 3.

Right ideas

1. The leaf is boiled in water to kill the cells. The leaf is boiled in chlorophyll rather to remove the chlorophyll
2. In testing for starch in a leaf, iodine solution gives a blue black color
3. NaHCO3 is added to the set up in testing for oxygen in order to produce more carbon dioxide. This is because lack of carbon dioxide in the set up will not make photosynthesis to take place.

STEP 4.

Reading Text: Texts on photosynthesis for week four

STEP 5

Answer the following questions

1. Describe an activity to test for starch in a leaf

………………………………………………………………………………………

WEEK FIVE (5)

STEP 1

Some people consider light and water as the most important conditions necessary for photosynthesis to occur. Explain with reasons whether this idea is true or false

ANSWER……………………………………………………………………

STEP 2

The table shows common misconceptions and the reasons of these misconceptions form.

WRONG IDEAS
1. In testing for light as a condition for photosynthesis, leaves are kept in a dark cardboard to enable more photosynthesis to take place
2. Every green leaf can be used for the experiment to show that chlorophyll is important for photosynthesis

These views are wrong scientifically

STEP 3.

Right ideas

1. To show that light is necessary for photosynthesis, leaves are kept in a dark cardboard to destarch the leaves and stop photosynthesis from taking place.
2. Only variegated leaves can be used to test for the presence of chlorophyll because it some portions can undergo photosynthesis whiles other portions cannot.

STEP 4.

Reading Text: **Texts on photosynthesis week 5**

STEP 5

Answer the following questions

1. What is the main product formed after photosynthesis

…………………………………………………………………………………

2. Describe an activity to show that carbon dioxide is necessary for photosynthesis

   ……………………………………………………………………………

WEEK Six (6)

STEP 1

Carbon dioxide concentration and light intensity are regarded as the most important factors influencing the rate of photosynthesis. Explain with reasons whether this claim is true or false.

ANSWER……………………………………………………………………

STEP 2

The table shows common misconceptions and the reasons of these misconceptions form.

WRONG IDEAS
1. As light intensity increases, both the light dependent stage and light independent stage increases proportionally.
2. Increase in carbon dioxide concentration increases the rate of photosynthesis because both the light independent stage and light dependent stage are affected.
3. Pollution, chlorophyll concentration and temperature have no effect on the rate of photosynthesis because they do not affect the light dependent stage directly.

These views are wrong scientifically

STEP 3.

Right ideas

1. Increase in light intensity increases the rate of photosynthesis. However, light intensity affects only the light dependent stage of photosynthesis. Light intensity does not affect the dark stage of photosynthesis.
2. Carbon dioxide concentration affects only the dark stage of photosynthesis and increase in carbon dioxide concentration leads to increase in the rate of photosynthesis but does not affect the light dependent stage.
3. Temperature, chlorophyll concentration and pollution also have effect on the rate of photosynthesis.

STEP 4.

Reading Text: Texts on photosynthesis week six

STEP 5

Answer the following questions

1. what is limiting factor

………………………………………………………………………………………

State three factors that affects the rate of photosynthesis

………………………………………………………………………………………

3. Explain one of the factors stated above

………………………………………………………………………………………

WEEK SEVEN (7)

STEP 1

Some students have the conception that the light stage is the most important stage in photosynthesis because that is the stage where sunlight is trapped to initiate the whole process.

Explain with reasons whether this claim is true or false.

ANSWER……………………………………………………………………………

STEP 2

The table shows common misconceptions and the reasons of these misconceptions form.

WRONG IDEAS
1. Both the light dependent stage and light independent stage occurs in the granum of the chloroplast
2. During the light stage, the chlorophyll after releasing electrons becomes negatively charged and stable
3. All the energy(ATP) produced during the light stage is used in photolysis of water in the light stage
4. All the Phosphoglyceraldehyde is converted into sugar during the dark stage reaction.

These views are wrong scientifically

STEP 3.

Right ideas

1. The light dependent stage occurs only in the granum of the chloroplast and is the first stage of photosynthesis whereas the dark stage occurs in the stroma of the chloroplast.
2. During the light stage, the chlorophyll after releasing the electron becomes positively charged and unstable
3. Part of the energy (ATP) produced during the light stage is used to reduce NADP to NADPH2 which is used in the dark stage.
4. Not all the Phosphoglyceraldehyde is converted into sugar during the dark stage reaction. Much of it is converted back into RuBp to ensure the continuity of the cycle.

STEP 4.

Reading Text: Texts on photosynthesis week seven.

STEP 5

Answer the following questions

1. State the factors affecting:

a. The light dependent stage of photosynthesis

……………………………………………………………………………………

b. The dark stage of photosynthesis

……………………………………………………………………………………

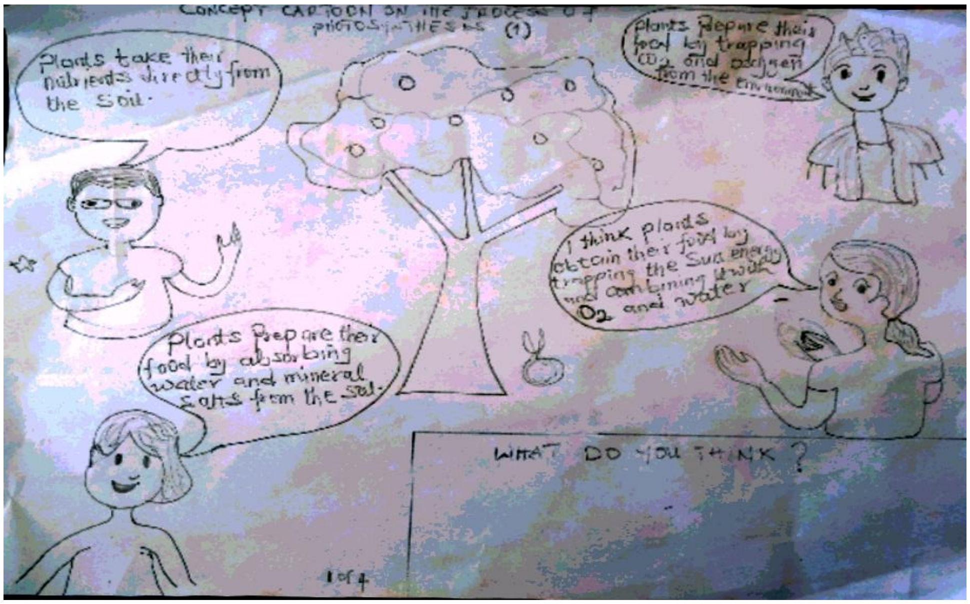
2. Briefly explain what happens during the dark stage of photosynthesis

…………………………………………………………………………………

APPENDIX E

CONCEPT CARTOONS LESSON

WEEK ONE (1)



STEP 1.

Observe the Concept cartoon above and write your idea on each of the cartoon character in the blank space provided.

……………………………………………………………………………………

STEP 2.

In a group of six, compare, argue and discuss your ideas. Write your ideas in the blank space provided

……………………………………………………………………………………

STEP 3.

One person in each group presents their ideas base on the concept cartoons.

STEP 4. Notes on photosynthesis for week one

STEP 5.

Answer the following questions

10. Define photosynthesis

…………………………………………………………………………………

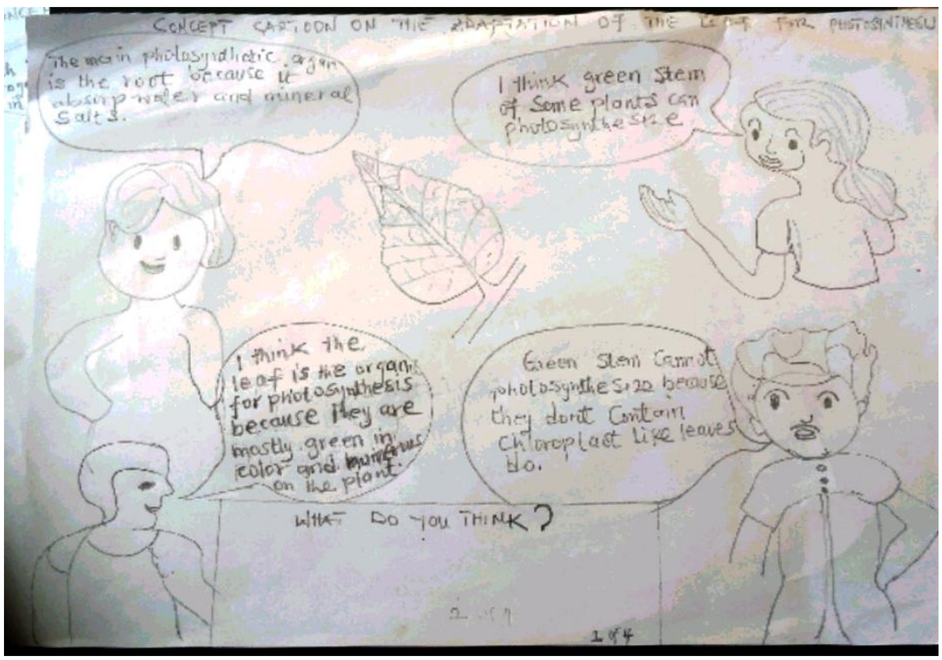
11. State two importance of photosynthesis

………………………………………………………………………………

12. Write a balance chemical equation for photosynthesis

……………………………………………………………………

WEEK TWO (2)



STEP 1.

Observe the Concept cartoon above and write your idea on each of the cartoon character in the blank space provided.

STEP 2.

In a group of six, compare, argue and discuss your ideas. Write your ideas in the blank space provided

…………………………………………………………………………………

STEP 3.

One person in each group presents their ideas base on the concept cartoons.

STEP 4. Notes on photosynthesis for week two

STEP 5

Answer the following questions

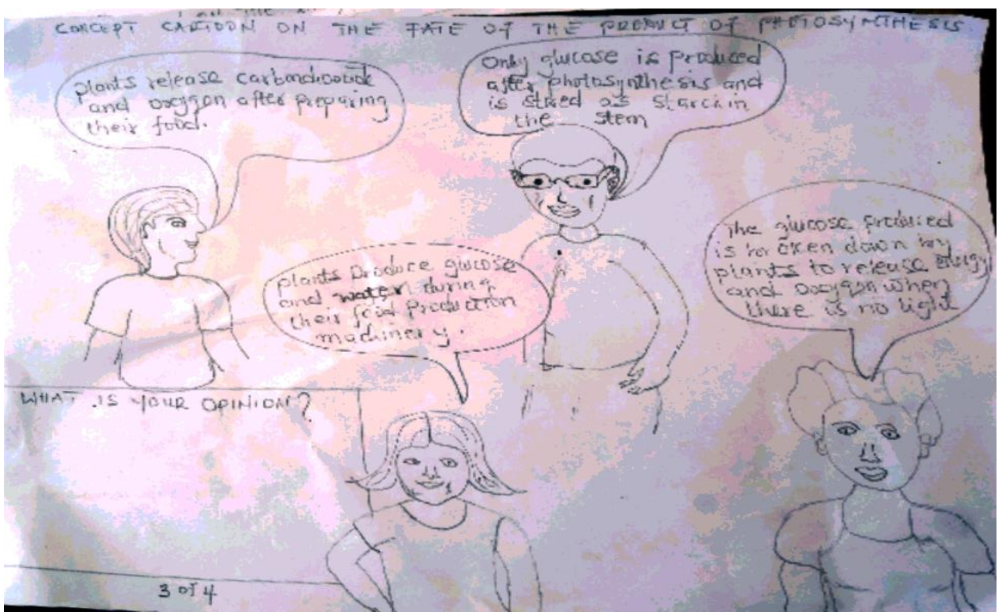
3. Explain how the leaf is adapted for photosynthesis

………………………………………………………………………………

4. Describe the longitudinal section of the leaf

………………………………………………………………………………

WEEK THREE (3)



STEP 1.

Observe the Concept cartoon above and write your idea on each of the cartoon character in the blank space provided.

………………………………………………………………………………

STEP 2.

In a group of six, compare, argue and discuss your ideas. Write your ideas in the blank space provided

……………………………………………………………………………………

STEP 3.

One person in each group presents their ideas base on the concept cartoons.

STEP 4. Notes on photosynthesis for week three.

STEP 5

Answer the following questions

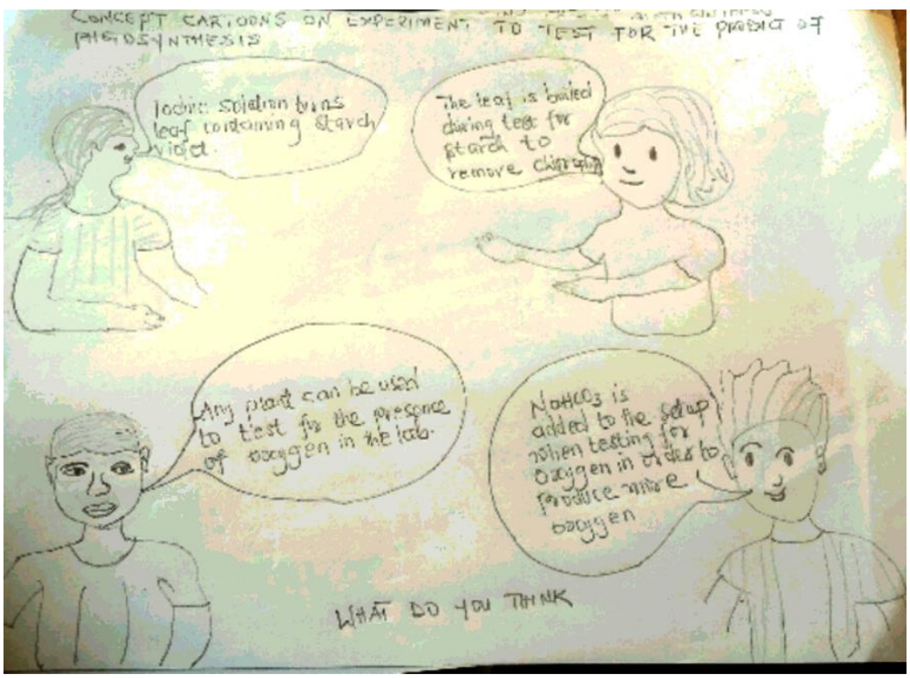
3. What is the main product formed after photosynthesis

……………………………………………………………………………

4. Describe the fate of the product of photosynthesis

………………………………………………………………………

WEEK FOUR (4)



STEP 1.

Observe the Concept cartoon above and write your idea on each of the cartoon character in the blank space provided.

……………………………………………………………………………………

STEP 2.

In a group of six, compare, argue and discuss your ideas. Write your ideas in the blank space provided

………………………………………………………………………………………

STEP 3.

One person in each group presents their ideas base on the concept cartoons.

STEP 4. Notes on photosynthesis for week four

STEP 5

Answer the following question

1. Describe an activity to test for starch in a leaf

………………………………………………………………………………

WEEK FIVE (5)

STEP 1.

Observe the Concept cartoon above and write your idea on each of the cartoon character in the blank space provided.

…………………………………………………………………………………………

STEP 2.

In a group of six, compare, argue and discuss your ideas. Write your ideas in the blank space provided

…………………………………………………………………………………………

STEP 3.

One person in each group presents their ideas base on the concept cartoons.

STEP 4. Notes on photosynthesis for week five

STEP 5

Answer the following questions

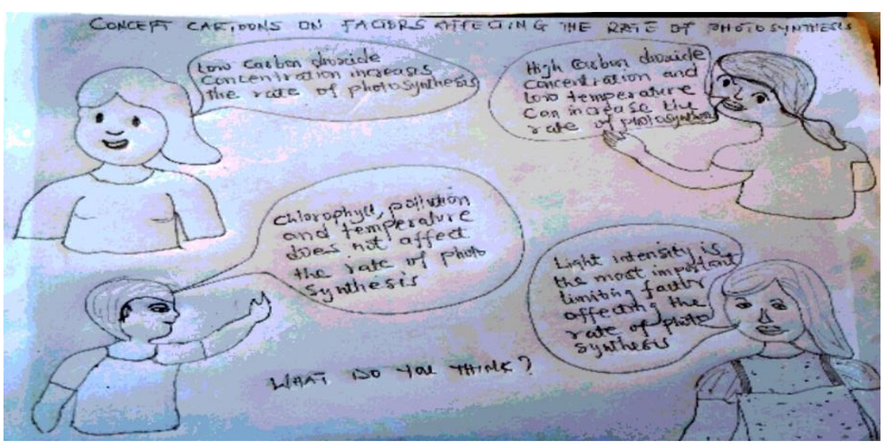
3. What is the main product formed after photosynthesis?

   ……………………………………………………………………………

   Describe an activity to show that carbon dioxide is necessary for photosynthesis

   ……………………………………………………………………………

WEEK Six (6)



STEP 1.

Observe the Concept cartoon above and write your idea on each of the cartoon character in the blank space provided.

…………………………………………………………………………………………
………………………………………………………………………………

STEP 2.

In a group of six, compare, argue and discuss your ideas. Write your ideas in the blank space provided

……………………………………………………………………………………

STEP 3.

One person in each group presents their ideas base on the concept cartoons.

STEP 4. Notes on photosynthesis for week six

STEP 5

Answer the following questions

1. what is limiting factor

………………………………………………………………………

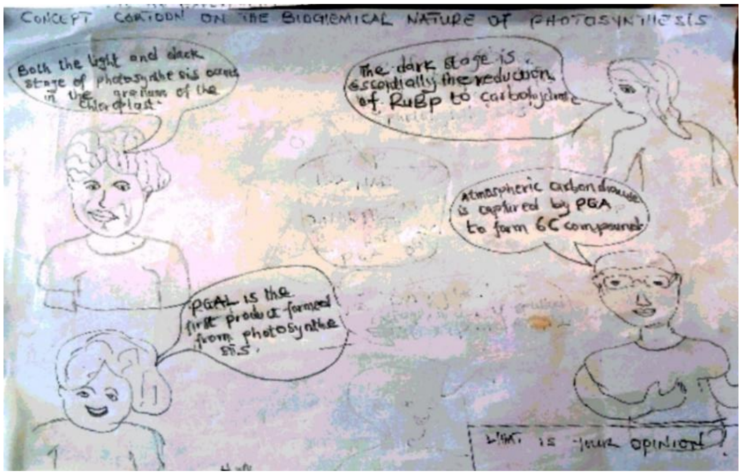
2. State three factors that affects the rate of photosynthesis

………………………………………………………………

3. Explain one of the factors stated above

……………………………………………………………

WEEK SEVEN (7)



STEP 1.

Observe the Concept cartoon above and write your idea on each of the cartoon character in the blank space provided.

………………………………………………………………………………………

STEP 2.

In a group of six, compare, argue and discuss your ideas. Write your ideas in the blank space provided

………………………………………………………………………………………

STEP 3.

One person in each group presents their ideas base on the concept cartoons.

STEP 4. Notes on photosynthesis for week 7

STEP 5

Answer the following questions

1. State the factors affecting:

   The light dependent stage of photosynthesis

   ………………………………………………………………………………

   The dark stage of photosynthesis ……………………………………

2. Briefly explain what happens during the dark stage of photosynthesis

   ………………………………………………………………………………

APPENDIX F

CONVENTIONAL APPROACH LESSON

WEEK ONE

STEP ONE

Introduction:

All living things need energy for survival. The question is, how is this energy produced and made available for all living things in the ecosystem? This energy is produced and made available by photosynthetic organisms in a process called photosynthesis. Therefore photosynthesis is regarded as the most important biological process on earth.

STEP TWO: Notes on photosynthesis for week one

STEP FOUR

Conclusion/Closure

All living organisms need energy for survival

This energy is made available by photosynthetic organisms

Photosynthesis is the most important biological process on earth because it provides food for all living organisms and removes excess carbon dioxide from the atmosphere

The raw materials for photosynthesis are water (H20) and carbon-dioxide (C02) and the energy required to drive this anabolic process is sunlight absorbed by chlorophyll.

WEEK TWO

STEP ONE

Introduction:

Leaves are plants main photosynthetic organ and its structure is closely associated with its function. The leaf is specially adapted for photosynthesis.

STEP TWO: Notes on photosynthesis for week two

STEP THREE

Application

Answer the following questions into your exercise book

1. Describe the structure of the leaf.
2. Explain why the leaf is adapted for photosynthesis.

STEP FOUR

Conclusion/Closure

The leaf is the organ for photosynthesis. The longitudinal section of the leaf reveals three main parts namely the epidermis, the palisade and the vascular bundle. The leaf is specially adapted for photosynthesis due to its special features.

WEEK THREE

STEP ONE

Introduction

After photosynthesis, glucose is produced as the main product whiles carbon dioxide is produced as the by product.

STEP TWO: Notes on photosynthesis for week three

STEP THREE

Application

Answer the following questions into your exercise book

1. What is the main product formed after photosynthesis
2. Describe the fate of the product of photosynthesis

STEP FOUR

Conclusion/Closure

The products formed after photosynthesis are glucose and oxygen. Oxygen is released into the environment and used by animals and humans whiles the glucose produced is stored as starch and is subsequently used to produce energy and synthesis of vital organic compounds.

WEEK FOUR

STEP ONE

Introduction

The products formed after photosynthesis (glucose and oxygen) can be tested in the laboratory using a potted plant and a pond weed.

STEP TWO: Notes on photosynthesis for week four

STEP THREE

Application

Answer the following questions into your exercise book

1. What is the main product formed after photosynthesis
2. Describe an activity to test for starch in a leaf

STEP FOUR

Conclusion/Closure

Blue black coloration is an indication that starch is produced during photosynthesis. Glowing splint is an indication of oxygen gas produced during photosynthesis.

WEEK FIVE

STEP ONE

Introduction

The conditions necessary for photosynthesis to occur can be tested in the laboratory. These conditions are light, carbon dioxide, chlorophyll and water.

STEP TWO: Notes on photosynthesis for week five

STEP THREE

Application

Answer the following questions into your exercise book

Describe an activity to show that carbon dioxide is necessary for photosynthesis.

STEP FOUR

Conclusion/Closure

The conditions necessary for photosynthesis to occur are sunlight, carbon dioxide, water and chlorophyll. These conditions can be experimented in the laboratory.

WEEK SIX

STEP ONE

Introduction

The main factors affecting the rate of photosynthesis are light intensity, carbon dioxide concentration and temperature. Other factors include chlorophyll and pollution.

STEP TWO: Notes on photosynthesis for week six

STEP THREE

Application

Answer the following questions into your exercise book

1. what is limiting factor
2. State three factors that affects the rate of photosynthesis
3. Explain one of the factors stated above

STEP FOUR

Conclusion/Closure

The main factors affecting the rate of photosynthesis are light intensity, carbon dioxide concentration and temperature. Other factors include chlorophyll and pollution. Limiting factors of photosynthesis are light intensity, carbon dioxide concentration and temperature.

WEEK SEVEN

STEP ONE

Introduction

The two main stages of photosynthesis are light dependent stage and light independent stage. The two main stages of photosynthesis are light dependent stage and light independent stage. During the light dependent stage, the leaf absorb carbon dioxide and water in the presence of sunlight to produce ATP, NADPH needed for the dark stage. During the dark stage glucose is produced using energy from the ATP and the NADPH.

STEP TWO: Notes on photosynthesis for week seven

STEP THREE

Application

Answer the following questions into your exercise book

1. Describe the light dependent stage of photosynthesis

STEP FOUR

Conclusion/Closure

Photosynthesis occurs in two main stages. These stages are the light stage and the dark stage. The light stage occurs in the grana. This stage consists of photolysis of water and reduction of NADP. This result in generation of ATP and NADPH which are used in the dark stage. During the dark stage, carbon dioxide is combined with RUBP and undergoes series of chemical reactions to produce glucose.