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Impact of 5es instructional model on science process-skills acquisition, performance and retention in photosynthesis among Senior High School Biology students, Akroso, Ghana

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IMPACT OF 5Es INSTRUCTIONAL MODEL ON SCIENCE PROCESS-SKILLS ACQUISITION, PERFORMANCE AND RETENTION IN PHOTOSYNTHESIS AMONG SENIOR HIGH SCHOOL BIOLOGY STUDENTS, AKROSO, GHANA

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A Thesis in the Department of Science Education, Faculty of Science Education, submitted to the School of Graduate studies, in partial fulfillment of the requirement for the award of degree of Master of Philosophy (Biology Education) in the University of Education, Winneba.

FEBRUARY, 2025

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DECLARATION

Student's Declaration

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

Candidate's Signature: …….

Date: ……

Supervisor's Declaration

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

Supervisor's Name: Dr. James Awuni Azure

Supervisor's Signature: ……

Date: ……

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DEDICATION

I dedicate this research work to my mother- Christiana Sarfoaa and siblings – Prince Osei, Benedicta Osei and Grace Elizabeth Osei.

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All glory and praise to God Almighty for His abundant mercies, unwavering guidance, and constant protection throughout this journey. May His name be exalted forever.

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ABSTRACT

This study investigates the impact of the 5Es Instructional Model on science process skills acquisition, academic performance, and retention in photosynthesis among senior high school biology students at Akroso Senior High Technical School, Ghana. Motivated by consistently poor student performance in biology especially in photosynthesis, a concept often misunderstood and poorly retained, the study applied a quasi-experimental design involving pre-tests, post-tests, and retention tests. Participants included 2024 third-year Home Economics students, divided into experimental and control groups.

The results revealed that students taught using the 5Es model scored significantly higher on post-tests and retention tests compared to those taught with conventional methods ($p < 0.05$). Specifically, the experimental group demonstrated improved science process-skills acquisition and deeper conceptual understanding of photosynthesis. Additionally, no statistically significant gender difference was observed in the performance or skill acquisition within the experimental group, indicating the model's effectiveness across genders.

These findings affirm the efficacy of the 5Es model in promoting active learning, critical thinking, and long-term retention. The study contributes to the call for student-centered, inquiry-based teaching strategies in Ghanaian science education.

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CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter outlines the background to the study, statement of the problem, the purpose of the study, educational significance of the study and the research questions and hypothesis addressed by the study. Also presented are the limitations and delimitation of the study. The chapter ends with the presentation of the operational definitions of terms used in the study as well as a description of the organization of the study.

1.1 Background of the Study

Education in the 21st century is characterized by a gradual shift towards equipping students with the skills they need to succeed in a rapidly changing world. This includes fostering creativity, encouraging collaboration, inspiring critical thinking, and teaching students how to learn.

The success and growth of nations powerfully connect to the quality of education provided to its citizens. This link between training and development informs the decision of several areas of the economy, including allocation of funds to the sector, as well as advancement of personnel capital and other resources to the education sector (Abreh, 2017; Blaug, 1970).

In the 2024 fiscal policy and budget statement delivered to Parliament, the Minister of Finance, Ken Ofori-Atta, reported that the Government of Ghana has allocated approximately GH¢8.4 billion over the past seven years toward strengthening second-cycle education through the implementation of the Free Senior High School (SHS) programme. Additionally, He further said that the government has allocated GH¢3.6

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billion to the School Feeding Programme (SFP) in order to boost enrollment and improve learning outcomes for approximately 3.8 million pupils at the basic level. Moreover, an amount of GH¢248.5 million has been allocated to Capitation Grants to strengthen foundational education for more than six million pupils.

Education is undeniably a cornerstone for the advancement of economies worldwide. Evelin Weber said “There is no better investment a nation can make than education. It is an investment in economic development, an investment in opportunity and an investment in our shared future”. The importance of mathematics and science education goes a step further in propelling economic growth, especially through science-driven technologies. The role of education in empowering individuals and systems is beyond dispute, and Ghana has embraced the power of mathematics and science to foster a technology-driven economy.

A compelling example of this lies in the various educational reforms made by the country over the years. The Government of Ghana began important changes to education in order to improve teaching and learning and enhance educational results as part of the Education Strategic Plan (ESP 2018-2030), which was officially approved by the cabinet in November 2018. The main focus of the education reforms is to bring about three key changes:

1. To improve the results and achievements of students in their learning.
2. To increase the responsibility and answerability of everyone involved in education.
3. To ensure fairness and equality at all levels of the education system.

The main reason for undertaking these significant changes is to make sure that our education system stays relevant to the evolving priorities of our nation's development

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and the new goals and ambitions we have. It's also to guarantee that our education system adapts to the current situation and time, including advancements in technology, industry, creativity, and the knowledge economy. These new reform efforts are designed to set clear performance expectations to direct how teachers teach, how students learn, how they are assessed, and how their work is graded. The reforms will also work to raise the professionalism of teaching and uphold high standards (The Ministry of Education).

Acknowledging the critical role of science in national development, the Ministry of Education has implemented various initiatives to guarantee equitable access to quality science education across all levels of the educational system. These initiatives are articulated in the Ministry's Education Strategic Plan (2018–2030), which outlines a key objective focused on improving the quality of teaching and learning in Science, Technology, Engineering, and Mathematics (STEM) education in all Senior High Schools throughout Ghana (National Development Planning Commission [NDPC], 2018).

However, contrary to the stated investment and benefits of science education in Ghana and despite the importance of Biology as a science subject, empirical studies such as those of Serwaa-Ampaafo (2017), Ganiyu and Isaac (2017) have shown that students still perform poorly in Biology at Senior Secondary School level.

Reports from several studies like Omorogbe and Ewansiha (2013) and Etobro and Fabinu (2017) have demonstrated that a wide range of factors contribute to this poor performance. Prominent among these factors include the difficult and abstract nature of a number of Biology concepts like Genetics, Evolution, Ecology, anatomy and physiology of plant and Cell Physiology, inadequacy and poor use of instructional

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materials, teachers' prevalent use of traditional teaching methods, lack of practical classes to foster acquisition of science process-skills and poor attitude of teachers towards teaching for better retention, among others.

The best strategy for science instruction and design has been the subject of countless historical attempts. Despite methodologies, techniques, and models have been developed, there has never been a perfect model. In this research, the 5E Model, a new model of one of the well-known approaches, Constructivism, is going to be introduced. This learning model includes activities which are crucial for fostering learners' research interests, addressing their expectations regarding the subject matter, and ensuring the efficient application of their knowledge and abilities (Ergin et al, 2006).

This model is founded on the principle that learners construct their own understanding of new concepts through active engagement, including investigation, experimentation, and the continuous refinement of their pre-existing knowledge and beliefs. Instead of only hearing about concepts and facts, students explore them during experiential learning. Positive changes take place in the pupils' perspectives, knowledge, skills, interests, and reasoning. The quality of the experience largely determines how much learning takes place (McElhane, 1998).

The 5Es Instructional Model is defined by Duran and Duran (2004) as a constructivist, problem-solving and inquiry-based model that uses five phases of instruction namely; Engagement, Exploration, Explanation, Elaboration and Evaluation as illustrated in figure one.

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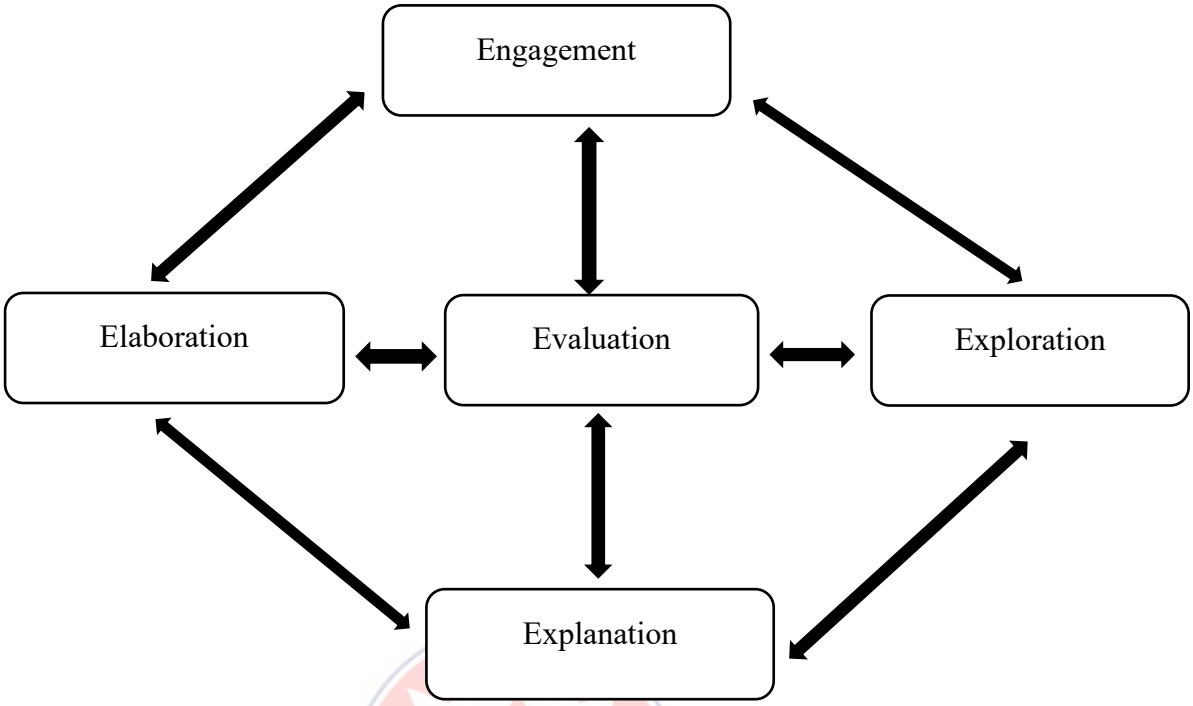

Figure 1: The 5Es instructional Model

According to O'Brien (2013), the 5Es Teaching Cycle represents an instructional framework designed to create a series of lessons rich in experimentation, with a clear conceptual connection and a developmental sequence. Its purpose is to facilitate the gradual and continuous improvement of students' understanding as it evolves over time. Senan (2013) elaborates that the 5Es Instructional Model was initially developed during the 1980s by the non-profit organization known as the Biological Sciences Curriculum Study (BSCS), under the leadership of Rodger Bybee. In contrast to traditional teaching methods such as lectures, where the teacher primarily imparts knowledge while students passively listen, the 5Es model strives to enable students to deduce concepts and principles through scientific investigations.

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Consequently, Boddy, Watson, and Aubusson (2003) emphasize that this approach not only helps students acquire content knowledge but also enables them to better retain that knowledge. Additionally, it fosters the development of scientific attitudes, science process skills, and cognitive abilities such as critical reasoning and problem-solving.

In biology classes, students learn key scientific concepts that help them understand how different processes on Earth work. One of these core concepts is photosynthesis, a vital process that occurs in plants.. Photosynthesis is a process by which plants convert light energy into chemical energy to produce glucose and oxygen (Campbell & Reece, 2008; Taiz & Zeiger, 2010). On account of its relevance, photosynthesis is part of the syllabus for science subjects of various levels of the education system, from primary schools to universities (Métioui, Matoussi & Trudel, 2015). Due to its complexity, the process also ranks among the most demanding science concepts (Marmaroti & Galanopolou, 2006; Güneş, Güneş & Hoplan, 2011). Photosynthesis is associated with a number of misconceptions, which is one of the reasons for poor understanding of the process. In biology, photosynthesis and cell metabolism have been identified as important, yet conceptually difficult areas (Stavy, Tsamir, & Tirosh 1987). The literature on 'misconceptions' or 'alternative frameworks' documents the difficulties that many students have in understanding these concepts (Stavy et al, 1987; Wandersee & Schussler, 1999). Several research reports like those from Ruiz and Mellado (2012), Marmaroti and Galanopoulou (2006) and Sadiq (2015) as well as WAEC Chief Examiner's Reports (2009-2018) agree on the difficulty of the topics under photosynthesis among students at the Senior High Schools. Analysis on examination questions of photosynthesis saw a significant decline in the frequency of photosynthesis-related questions in May/June WASSCE examination from the years

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2009-2018. Is WAEC reducing photosynthesis related questions because of its difficulties?

This difficulty is evidenced by the recurrent failure recorded by candidates in questions associated with the concept in external Biology examinations like WASSCE. Therefore, the 5Es Instructional Model is to be employed in this study perhaps as a possible means of remediating this difficulty and enhancing senior high school students' retention of this concept.

The ability of a learner to store information which can be recalled at a later time after exposure to a series of instruction or training is referred to as retention (Jiya, 2011). According Sanz and Hovell 2021, knowledge retention is the capability to retain unique and critical knowledge, whether tacit, explicit, or implicit. Wada (2016) emphasized that the proper encoding of information serves as a reference point for retention, enabling it to occur without the need for extensive memory searching. As a result, robust retention of acquired concepts signifies a solidified learning process and promotes the application of knowledge for problem-solving. Ibrahim (2015) identified various factors that can contribute to students' retention, and one of these factors is the instructional approach used when teaching a particular concept. Several researchers, including Ergin (2006), Bunkure (2012), Ibrahim (2015), and Anil and Batdi (2015), have demonstrated that the retention of scientific concepts is more effectively improved through the use of the 5Es Instructional Model compared to the Traditional Lecture Method.

The difference between educational developments of traditional educations, compared with application of 5E model is quite clear, application of 5E is effective in deep learning. Also, students' attitudes toward a subject matter are more positive when using

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5E model. This model was used for science subject matters like physics, power, and mechanic. Results showed that 5E is effective not only in education but in students positive views toward the subject matter (Ossevgee, 2007). In teaching chemistry, results also showed that the attitude of students using 5E model, comparing to traditional methods, were more positive and more successful in gaining scientific skills in a research based on applying 5E, also students of the fifth grade in elementary schools were more successful in gaining scientific skills based on using the 5E instructional system since they were successful compared with the control group (Cheng, Nadkarni, Mancini, Hunt, Sinz, Merchant, Donoghue, Duff, Eppich, Auerbach, Bigham, Blewer, Chan, & Bhanji 2008). Gender has also been a variable that has garnered significant attention from researchers in the field of science education. It is conceivable that gender disparities might influence the development of Science Process Skills, ultimately impacting students' overall academic performance. Research on how gender affects students' learning of science process skills and academic achievement has so far shown conflicting results. Research conducted by Hines (2007), and Viadero (1998) collectively suggests that gender does not have a significant impact on students' ability to acquire and master science process skills. On the other hand, research by Ong, Wong, Sopia, Sadia, Asmayati, and Zahd in 2012, Zeidan and Jayosi in 2015, and Ongowo in 2017 has shown data that shows there are significant differences between male and female students in terms of their learning of science process skills. In addition, studies examining the connection between gender and academic achievement, such as those by Akolonu (2001), Umar (2013), Kyei and Benjamine (2011), and Armah, Akayuure, & Armah (2021) have demonstrated that males outperform females, especially in mathematics and science. Contrarily, in almost all academic disciplines and at all levels of education, women are outperforming men, according to recent studies in the

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developed world (Grant & Behrman (2010); Morita, Shimizu, & Kobayashi., 2016; Perez-Felkner, Benenson, & Heller, 2012; Workman and Heyder, 2020). Workman and Heyder (2020) contend that, despite the natural sciences traditionally being a domain dominated by men, girls appear to perform better than males in language, and the arts as well. You and Sharkey (2012) also point out that females' greater academic achievement at primary and higher education levels does not represent their enrollment in simpler classes or courses, but rather the competencies women possess in all areas of learning.

1.2 Statement of the Problem

The performance of students in Akroso Senior High Technical School in elective biology has been very poor over the years. This is evident in their poor performance in the biology during West African School Certificate Examination (WASSCE) over the years. The percentage pass of students in biology in 2020, 2021, 2022 and 2023 was 35%, 4.5%, 50% and 8.9% respectively. This pervasive underperformance raises concerns about the effectiveness of the current instructional methods employed by teachers in teaching biology. Parents and the school management has shown great concern about the poor performance of students in biology. This concerns is seen to be legitimate as a pass in biology is a requirement needed by most tertiary institutions for further studies. A number of factors have been identified as major contributory factors to this poor performance. Some of these factors include insufficient practical work in biology (Serwaa-Ampaafo,2017), qualification, resourcefulness and experience of teachers. Mamalanga and Awelani (2014), also noted that the possible factors responsible for the poor performance in biology included among other things is the poor traditional method of teaching and assessing biology.

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Amadu, Syed Muhammad, Mohammed, Owusu, & Lukman (2018), stated that one of the disturbing factors contributing to poor academic performance among biology students is how lessons are delivered by the teachers. Teachers continue to use the traditional lecture method in teaching biological concepts in most of the secondary schools in Ghana. This approach has a heartbreaking outcome as students misses out on truly grasping the core concepts being taught. Instead, they are compelled to rely on mindless memorization and rote learning just to pass exams. Sadly, this leads to dismal performance when they inevitably forget everything they crammed.

Azure (2015), stated that instructional approaches that demand students' active participation in task accomplishment is missing in the typical Ghanaian classroom. In order to improve students' performance and arouse their interest in learning biology, activity based instructional approach must be adopted to enable the learners acquire the cognitive competences so they can pass biology. Hawkins and Williams (2020), stated that it is uncommon to expect students to develop the necessary 21st century skills in a traditional classroom because characteristically, lessons designed in the traditional classroom setting do not create opportunities for students to critically think, collaborate with other students or become problem-solvers, nor do they allow students to practice how to connect new information with experiences outside the classroom setting.

One of the instructional strategies that engage, motivate and promote students' critical thinking is the 5E instructional model which provides research-based learning cycles in five phases which are engagement, exploration, explanation, extension and evaluation (Hawkins & Williams, 2000).

Other empirical studies like that of Biyikli (2013), Acisli (2014), Ozturk, Geren and Dokme (2015) and Cakir (2017) have indicated the efficacy of 5Es Instructional Model

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in enhancing the acquisition of science process-skills among students. Most of these studies are done outside Ghana. Local literatures in this subject seem to be very limited. This study therefore aims to identify the root causes of students' poor performance in biology, particularly in WASSCE, and to assess the efficacy of the 5Es instructional Model to address these issues by improving students' acquisition, performance, and retention of science process skills related to photosynthesis.

1.3 Purpose of the Study

The purpose of the study is to determine the impact of 5Es instructional model on science process-skills acquisition, performance and retention in photosynthesis among senior high school biology students in Akroso Senior High Technical School.

1.4 Objectives of the Study

The objectives of this study are to:

1. examine the impact of 5Es Instructional Model on the acquisition of science process-skills in photosynthesis among senior high school Biology students.
2. examine the impact of 5Es Instructional Model on the acquisition of science process-skills in photosynthesis among male and female senior high school Biology students.
3. examine the impact of 5Es Instructional Model on the academic performance of senior high school Biology students in photosynthesis.
4. examine the impact of 5Es Instructional Model on the academic performance of male and female secondary school Biology students in photosynthesis.
5. examine the impact of 5Es Instructional Model on the retention ability of secondary school Biology students in photosynthesis.

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1.5 Research Question

The following research questions will be formulated for answering:

1. What is the difference between the mean academic performance scores of senior high school Biology students taught photosynthesis using 5Es Instructional Model and those taught the same concept using Conventional Method?
2. What is the difference in the mean science process-skills acquisition scores of senior high Biology students taught photosynthesis using the 5Es Instructional Model against the Conventional Method?
3. What is the difference in the mean science process-skills acquisition scores between male and female secondary school biology students taught photosynthesis using the 5Es Instructional Model?
4. What is the difference between the mean academic performance scores of male and female secondary school Biology students taught photosynthesis using 5Es Instructional Model?
5. What is the difference between the mean retention scores of secondary school Biology students taught photosynthesis using 5Es Instructional Model and those taught the same concept using Conventional Method?

1.6 Research Hypothesis

Based on the objectives and research questions stated, the following research hypotheses are formulated for testing at $p \leq 0.05$ level of significance:

Hypothesis 1: There is no statistically significant difference between the mean academic performance scores of secondary school Biology students taught photosynthesis using 5Es Instructional Model and those taught the same concept using Conventional Method.

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Hypothesis 2: There is no statistically significant difference between the mean science process-skills acquisition scores of secondary school Biology students taught photosynthesis using 5Es Instructional Model and those taught the same concept using Conventional Method.

Hypothesis 3: There is no statistically significant difference between the mean science process-skills acquisition scores of male and female secondary school Biology students taught photosynthesis using 5Es Instructional Model.

Hypothesis 4: There is no statistically significant difference between the mean academic performance scores of male and female secondary school Biology students taught photosynthesis using 5Es Instructional Model.

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

These research hypotheses have been tested using appropriate statistical analysis to determine the impact of 5Es problem-solving model on science process-skills Acquisition, performance and retention in photosynthesis among senior high school biology students. The outcomes of the study will provide empirical evidence to either accept or reject theses research hypotheses.

1.7 Significance of the Study

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

The findings from this study are expected to help Biology teachers by demonstrating effective methods and emphasizing the importance of using the 5Es Instructional Model to teach challenging concepts in Biology, such as photosynthesis.

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This study aims to equip Biology students with essential inquiry skills, social interaction, creative thinking, problem-solving abilities, and scientific process skills. It is anticipated that this approach will foster a positive attitude toward learning challenging Biology topics, such as photosynthesis, and potentially improve students' academic performance and retention in these areas.

This study could benefit higher education institutions, such as Colleges of Education and Universities, that train Biology teachers by providing resources on the 5Es Instructional Model. Access to these resources would enable lecturers to thoroughly prepare future teachers, who can then apply this approach to support their students' learning at the secondary and basic education levels.

This study will also benefit researchers by adding to the body of literature on the 5Es Instructional Model and encouraging further research. New findings from these studies could collectively enhance Science Education, particularly Biology education, in Ghana.

EDUCATION FOR SERVICE

1.8 Delimitation of the Study

This research aims to examine the influence of the 5Es instructional Model on the development of science process skills, academic achievement, and retention of knowledge in the context of Photosynthesis among second-year students (Form II) studying Biology in public Senior High Schools (SHS) in the Asene Manso Akroso District Education Zone, located in the Eastern Region of Ghana. Second-year (SHS 2) students have been selected as the target population for this study because they exhibit stability and possess foundational knowledge of basic Biology concepts gained in the previous academic year (SHS 1).

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In this study, we will be assessing Basic Science Process Skills (BSPS), which encompass key skills such as observation, communication, classification, measurement, inference, prediction, data Collection and recording, and drawing. These BSPS have been chosen as the primary focus due to that fact such skills are often emphasized in science education to help students develop a solid foundation for scientific thinking and problem-solving. Moreover, they are operationally less complex, intellectually less demanding, and can be seamlessly integrated with content learning, as suggested by Karamustafaoglu (2011) and Ongowo (2017).

1.9 Limitations of the Study

To keep it focused and feasible, this study is limited in a number of ways:

Geographical Focus: Because the study is specifically focused on biology students in Asene Manso Akroso educational zone, it is possible that its conclusions cannot be applied to other geographic or educational contexts.

Timeframe: The research will be carried out within a set timeframe and doesn't go past the allotted research period.

Academic Level: The study will mainly focus on biology instruction at the secondary school level and how well students perform on the West African Senior School Certificate Examination (WASSCE). The circumstances of tertiary or higher education are outside the purview of this study.

Instructional Approach: Although the study will investigate the effects of the 5Es Problem-Solving Model on the acquisition, performance, and retention of science process skills in photosynthesis, it does not examine other teaching strategies or subjects covered in the broader biology curriculum.

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Gender Perspective: The research will examine how gender affects biology performance, but it will not fully explore all the gender-related aspects that might have an impact on academic results.

1.10 Operational Definition of Terms

5Es Instructional Model: An approach to teaching that emphasizes constructivism, problem-solving, and inquiry-based learning, organizing learning experiences so that students can gradually build their understanding of a concept. This method includes five instructional phases: Engagement, Exploration, Explanation, Elaboration, and Evaluation.

Conventional Method: The conventional method of teaching, also known as traditional teaching, typically involves a teacher-centered approach where the teacher is the primary source of information. Lessons are often delivered through lectures and direct instruction, with students taking a more passive role by listening and taking notes. The focus is on memorization and repetition, and assessments usually consist of tests and quizzes to evaluate students' retention of facts and information.

Science Process-Skills: Cognitive and psychomotor skills employed in scientific investigations and problem solving which are acquirable or developed by students through training and practice. Science-process skills are the fundamental abilities that enable students to effectively engage in scientific inquiry and problem-solving. These skills include observing, classifying, measuring, inferring, predicting, experimenting, and communicating findings. They help students develop a deeper understanding of scientific concepts and methods by promoting active participation in scientific practices.

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

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Process-Skills Acquisition: The outcome of students' competency in utilizing their knowledge of or acquired science process-skills to solve problems. The emphasis is on cultivating the skills necessary to explore questions and perform experiments, fostering students' independence as learners and thinkers. This method encourages experiential learning, enabling students to actively engage and apply their knowledge in real-world situations.

Retention: It refers to a learner's capacity to retain information following a set of lessons or training, which can be remembered and recalled later.

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

1.11 Organization of the Study

This study report is presented under five chapters.

Chapter One provides an introduction and sets the stage for the research. It begins with a general overview of the study, outlining the problem being addressed and the rationale behind it. The chapter also describes the purpose of the research, alongside its limitations, scope, and relevance to existing studies. Additionally, the specific objectives, research questions, and hypotheses are explained. To ensure consistency and clarity, the chapter ends with definitions of key terms as they are used in subsequent sections.

Chapter Two delves into a review of related literature, offering insights into the theoretical framework and the historical background of science education in Ghana. It discusses various topics, including the philosophy and objectives of science and biology

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education, challenges faced in teaching and learning biology in senior secondary schools, and trends in student performance, especially in topics like photosynthesis. Furthermore, it examines the importance of science process skills, strategies for effective biology instruction, and the 5Es instructional model. The chapter closes by exploring how the 5Es model impacts academic performance and knowledge retention in biology.

Chapter Three explains the methodology used in the study. It details the research design, describes the area and population involved, and outlines the tools and procedures used to collect and analyze data. The chapter emphasizes the systematic approach adopted to ensure the validity and reliability of the findings.

Chapter Four presents the research findings and provides a detailed discussion of the results. This chapter interprets the data within the context of the research objectives.

Chapter Five wraps up the study with a summary of the main findings and conclusions drawn from them. It also provides recommendations as well as ideas for further research to address gaps.

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CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter reviews relevant and related literature on the topic of the research and are presented under the following sub-headings: Theoretical framework of the study; Historical Perspective of Science Education in Ghana; Philosophy and Objectives of Science Education; Philosophy and Objectives of Biology Education; Problems of Teaching and Learning Biology in Ghana Senior Secondary Schools; Students' Academic Performance in Biology at Senior Secondary Schools; Trends of Senior Secondary School Students' Performance in Photosynthesis; Science Process-Skills Acquisition among Senior Secondary School Students; Relevance of Science Process-Skills to Science Education; Instructional Strategies in the Teaching and Learning of Biology; The Concept of 5Es Instructional Model and 5Es Instructional Model and Academic Performance and Retention in Biology;

2.1 Theoretical Framework

Constructivism Learning Theory served as the foundation for this study, specifically the Theory of Cognitive Constructivism proposed by Piaget in 1973 and the Theory of Social Constructivism by Vygotsky in 1978. The central idea of CLT is that learners actively construct new knowledge on the foundation of pre-existing knowledge (McLeod, 2019).

Piaget (1970) believed that people learn by actively interacting with the world around them and forming mental structures or concepts based on these experiences. According to Piaget's theory of cognitive constructivism, students can create their own understanding of new concepts by combining the new information with their existing

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knowledge, beliefs, and abilities (Erickson &Verstynen, 2017). Piaget (1970) believed that learning is an active process where students construct knowledge through exploration, discovery, and problem-solving. He believed that this leads to the creation of schemas or mental modes that facilitate learning. Constructivism is frequently promoted as a way to examine children's comprehension and to show that their understanding can increase and change to higher level thinking (Mvududu & Thiel-Burgess, 2012).

The 5Es instructional model is a constructivist teaching strategy that aligns with the principles of constructivism, which suggests that learners construct their own understanding through experiences and interactions with the world. Developed by the Biological Sciences Curriculum Study (BSCS), the 5Es model includes five phases: Engage, Explore, Explain, Elaborate, and Evaluate. Each phase supports students' active participation in the learning process, allowing them to build knowledge step by step. The 5Es Model engages students both mentally and physically by allowing them to manipulate instructional materials in experimental conditions. The students also engage in critical and reflective thinking to find plausible explanations for scientific phenomena or answer thought-provoking questions posed by the teacher. In this context, the 5Es learning cycle allows students to gain and master science process skills while also developing their cognitive and psychomotor talents by working in an atmosphere that promotes intellectual soundness and physical dexterity. Students' retention abilities improve as a result of the depth with which learned information is processed.

Social constructivism is a learning theory propounded by Lev Vygotsky in 1968. The theory states that language and culture are the frameworks through which humans

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experience, communicate, and understand reality. According to Vygotsky (1968), language and culture play essential roles both in human intellectual development and in how humans perceive the world. The social constructivist views knowledge as something children have in partnership with other students, teachers, and peers. This style of cognitive constructivism promotes collaborative Learning, either with a facilitator or with other students (Mohammed & Kinyo,2020. Social constructivism emphasizes the value of communication, teamwork, and information usage in the learning process, viewing these components as necessary to meet educational goals. One of the main proponents of this theory, Vygotsky, suggested that social learning occurs in social settings and that social interaction is necessary for continuous personal development. Active student participation, discussion, and idea sharing are given top priority in this teaching methodology. Its emphasis on collaborative learning and shared understanding is shown in the ways it fosters different kinds of group work and interactive methods. Whole-class conversations, small-group discussions, and student involvement on specific topics (for example, in pairs). Students share ideas and brainstorm to find cause-and-effect links, answers to problems, or just something new to add to their existing Knowledge (Al-Qaysi, Mohamad-Nordin & Al-Emran, 2020). Learning is presented in a social context using the 5Es Instructional Model. Throughout the 5Es lesson, students collaborate with their peers to develop new ideas based on prior knowledge, engage in activities or experiments, seek explanations for scientific phenomena, come up with solutions to problem. With the teacher's guidance, the students explore how the concepts can be applied to real-world situations. The teacher organizes the class into small, interactive groups, fostering a productive learning environment both within and among them. In this classroom setting, students benefit from their own experiences, those of their peers, and the teacher's insights. As students

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interact with people, the material and immaterial environment, they gain understanding and gather experience which is needed to live successful and functional lives. As a result, students have the opportunity to improve their communication skills. Positive interdependence among these students helps them to form memories that improve their ability to retain information. Continuing with this notion, the current study focuses on the development of science process skills, academic performance, and knowledge retention in secondary school biology students in Akroso Senior High Technical School. It does this by employing the 5Es Problem-Solving Model to teach photosynthesis concepts.

2.2 Historical Perspective of Science Education in Ghana

According to Omiko (2015) and Ibrahim (2015), the beginning of science and science education may be as old as the human race itself, coming from man's desire to pass on the knowledge, ideals, values, and norms he had learned from solving the problems that threatened his survival to the next generation.

Ghana has been a pioneer in modern mass education in West Africa. The development of education in Ghana is closely tied to the socio-political changes that have taken place from colonial times to the present day. Education was mainly informal, and based on apprenticeship before the arrival of European settlers. The earliest recorded history of formal education in Ghana is linked directly with the history of European activities on the Gold Coast. The Portuguese were the first European settlers to arrive at the then Gold Coast in 1471. In 1529, the then Governor of the Portuguese Castle at Elmina in Ghana supported the notion to teach reading, writing, and the Catholic religion to the people. However, this was only targeted at populations linked with their social,

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economic and religious interests (Adu-Gyamfi, Donkoh & Addo, 2016) (Graham, 1971).

The effort to provide Christian education on the Gold Coast took a decisive turn with the arrival of Wesleyan and Basel missionaries in 1835. Despite the achievements on the coast, efforts to open schools in the mainland areas of the then Gold Coast faced some friction from local dwellers. Apparently, some of the local chiefs in these areas expressed fear that the western-style education would negatively impact local values and culture. Wesleyan efforts to conduct schools continued to be limited to just the coast throughout the nineteenth century (Graham, 1971). Education followed this path till Ghana's independence in 1957.

2.2.1 Major Educational Reforms after Independence (1957)

Several Educational Reforms have been initiated over the years aimed at finding lasting solutions to problems concerning education in Ghana. Below is a discussion of the various educational reforms initiated and implemented by successive governments after independence with the quest of providing Ghanaians with a good and workable educational system. These reforms include:

2.2.2 The Accelerated Development Plan of 1951 and Education Act of 1961

This is the first education reform initiated by the first prime minister of Ghana, Dr Kwame Nkrumah after independence from colonial rule. It was aimed at rapidly expanding the educational system, and also recognizing the importance of teacher training schools to have enough quality trained teachers to teach in schools. This seven-year development plan did not abandon the service of untrained teachers at the time who were helping to man the classrooms until trained teachers were produced. However, it is relevant to acknowledge the fact that, Dr. Kwame Nkrumah's proposed

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reforms after self-governing was to ensure the recognition of African identity by embarking on a system which trained teachers from the African standpoint. This initiative was probably an attempt to eradicate western thoughts and culture from the minds of Ghanaians. As such, Nkrumah's reforms introduced subjects pertaining to African Cultural identity, values and practices. Again, the local dialects (region specific) were used as a medium of instruction in the lower primary schools to groom the students till, they reached upper primary level and from there to all higher levels, English was then used as a medium of communication (Adu-Gyamfi, Donkoh and Addo, 2016) (Akyeampong, 2017).

In accordance with this act, the central government helped built approximately fifteen new secondary schools in different regions of Ghana. Also, several technical institutions were established to boost the Technical/Vocational sector for effective productivity. The plan also introduced a complete structural process which comprised of 10 years of elementary education (primary school and junior high school) combined with a free textbook scheme.

2.2.3 Reforms of the National Liberation Council

A new regime emerged after an organized coup d'etat in 24 February 1966 by the National Liberation Council (NLC) comprising of both military and civilian officers overthrew the first prime minister of Ghana, Dr. Kwame Nkrumah's government. This exercise was the first mode of acquisition of power in the history of Ghana. To recover the grave economic situation in the country, the NLC made few major decisions regarding the educational sector by forming a new Education Review Committee to undertake a comprehensive review of the entire formal educational system. However, the government was quick to abandon the Seven-Year Development Plan initiated by

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Dr. Kwame Nkrumah and modifying the free textbook scheme to allow parents to pay part of the cost of the distribution of textbooks to students. The structure of the education system under the NLC was such that the ten (10) years of elementary education by the Nkrumah government was reduced to eight (8) years to prepare students for secondary schools' entry and an additional two (2) year continuation course of middle school. The entry requirement of secondary schools rested on the Common Entrance Examination by students in their final eighth year. The secondary school lasted for five (5) years to prepare students for the West African Examinations which was used as an entry requirement for university education, which was four (4) years (Adu-Gyamfi, Donkoh and Addo, 2016).

2.2.4 The New Structure and Content of Education of 1974

Since Ghana's independence, succeeding governments have shown recognition for the significance of education to national growth. In 1974, a new military government led by Colonel I. K Akyeampong who also came into power via a coup d'etat to overthrow the previous government headed by Dr Bussia. Colonel Akyeampong formed a new committee known as the Dzobo Committee, to review the then state of education in Ghana. Findings from this report led to the restructure of the education which introduced the concept of the Junior Secondary School (JSS) and the Senior Secondary School (SSS). Pre-tertiary education was reduced from seventeen (17) to thirteen (13) years. Interestingly, the six (6) years of primary education remained the same, the four years of middle school which is equivalent to junior secondary school was reduced to three years. Also, senior secondary school was reduced from five years to four years. The central idea behind these reforms was to enable graduates to develop skills that will be beneficial in the job markets or even make them self-employed. The enactment of this reform began on an experimental basis where new subjects such as Tailoring,

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Woodwork, Catering, Dressmaking, Metalwork, Technical Drawing Masonry and Automobile Practice were introduced (Adu-Gyamfi, Donkoh and Addo, 2016) (Owusu Mensah, 2008).

2.2.5 Educational Reform of 2007

The New Patriotic Party (N.P.P.) won power in the 2000 general elections in Ghana. After two years in government, President John Agyekum Kuffour inaugurated a committee to review the existing education system in Ghana at the time. Reports from this committee also led to some reforms. The main idea of the reform includes formation of human capital for industrial growth, preservation of cultural identity/traditional indigenous knowledge or creativity and also improvements in science and technology (Ghana, 2009). This reform extended Senior High School (SHS) education from three (3) to four (4) years. The first year of SHS was dedicated to study "core subjects" such as English Language, Mathematics, Integrated Science, Information Communication Technology (ICT) and Social Studies. Recommendations from this committee were the inclusion of two (2) years Kindergarten into the Universal Basic Education hence making it eleven (11) years of Universal Basic Education. The Universal Basic Education was structured into two (2) years of kindergarten, six (6) years of Primary Education, three (3) years of Junior High School (JHS). Also, emphasis was placed on Literacy, Numeracy and Creative Arts at the basic level and the change from three (3) years of Senior Secondary School (SSS) to four (4) years of Senior High School (SHS) (Adu-Gyamfi, Donkoh and Addo, 2016). The reason was to ensure that teachers have enough time to finish the syllabus and give students adequate time to prepare `for the West African Secondary School Certificate Examination (WASSCE). However, a study revealed that students under the 3-year system scored higher grades than students from the 4-year system. This led it to be changed back to

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three years by the Atta-Mills government after an election victory in 2008 (Ghanaweb, 2009).

2.2.6 Reforms of 2017

Again, a new government led by President Nana Addo Danquah in 2017 brought free education to secondary school level, which was an upgrade on the free compulsory basic education (Free SHS - Wikipedia, 2018). This system also brought pressure unto the education system in Ghana in terms of facilities, teachers etc. As such a new system of schooling was also introduced to cope with these pressures, the two-track system. Some children go to school while others take a break. So far, it has succeeded in wedging more students into classrooms. However, supporters say it is a temporary solution while more teachers are hired, and schools are built.

2.2.8 Current structure of the Education system in Ghana

• Basic education level: Basic Education lasts 11 years and the curriculum is free and compulsory (age 4-15) and is defined as "the minimum period of schooling needed to ensure that children acquire basic literacy, numeracy, and problem-solving skills as well as skills for creativity and healthy living". It is divided into Kindergarten, Primary school and Junior High School (JHS), which ends with passing the Basic Education Certificate Examination (BECE). – comprising kindergarten (two years), primary (six years) and junior high school (three years) (Education in Ghana - Wikipedia, 2018).

• Second cycle education: three years – consisting of senior high school grammar and technical education, as well as other post-basic skills-development programmes, including the National Apprenticeship Programme. Students in this phase undertake another standardised test called the West African Senior School Certificate Examination (WASSCE) at the end of the three-year secondary education. Students can then move

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on to university, technical university (formerly called polytechnics), colleges of education or other forms of specialized training institutions after the WASSCE. Moreover, after passing the BECE, students who wish to also pursue vocational Education can follow the vocational and technical pathways. They can then proceed to join a university or polytechnic programme dependent on passing their WASSCE (Education in Ghana - Wikipedia, 2018) (Bibby & Peil, 1974).

• Tertiary level education: comprising diploma programmes at teacher training institutions and polytechnics, as well as undergraduate programmes spanning a minimum duration of three years (for diploma programmes) and four years (for undergraduate degree courses). Master's programmes are usually an average of two years while PhD takes 3-4 years. Ghana also possesses many specialized colleges of education (e.g., Nursing training colleges and teacher training colleges). Students are accepted into these institutions through a competitive selection process following successful pass in their WASSCE. New tertiary education graduates are mandated to serve one year within the National Services. (Education in Ghana - Wikipedia, 2018).

2.3 Philosophy and Objectives of Science Education

Philosophy of the curriculum

Ghana's curriculum concept for science education has its roots in the nation's emphasis on cultural relevance and holistic development. It aims to give students the information, abilities, and capacity for critical thought needed to interact with the scientific community and advance society.

Key principles guiding science education in Ghana include:

- Learner-centered approach: The curriculum places a high priority on students' needs and interests, encouraging engagement and inquiry-based learning.

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- Cultural relevance: To make science instruction meaningful and applicable to students' daily lives, Ghanaian cultural values, customs, and history are incorporated into the curriculum.
- The curriculum strives to increase students' scientific literacy by helping them comprehend scientific ideas, procedures, and applications. This will empower them to engage in scientific dialogue and make well-informed judgments.
- Critical thinking: Learning science helps students develop their critical thinking abilities, which enable them to assess the data, weigh the pros and cons of various viewpoints, and come to reasoned conclusions.
- In order to prepare students for professions in science or for being informed citizens, the curriculum places a strong emphasis on the development of practical skills including observation, experimentation, and data analysis.

Objectives of the curriculum

The Curriculum Framework has been developed with the following overarching goals in consideration, serving as the foundational principles for all teaching and learning programs and classroom activities at the basic education level. These objectives are as follows:

- Provide learners with broad up-to-date knowledge, skills, values and attitudes in both existing and new subject disciplines and in a range of foundational literacies;
- Develop in learners the ability to apply what they have learned with confidence and competence in the world of work;
- Instill in learners an understanding of Ghana's history, culture and traditions and of their rights and responsibilities as citizens;

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- Encourage learners to fully participate in the learning process and to promote learning as a lifelong endeavour;
- Encourage and support teachers to engage in creative and dialogic instructional practices;
- Promote an inclusive educational system where individual strengths and potentials are valued and maximised, regardless of ethnicity, religion, gender, geographical location or disability;
- Encourage learners to learn mathematics as a foundational building block to learning other subjects;
- Instill in learners the importance of making responsible choices regarding the environment and climate;
- Promote financial literacy to include the development of entrepreneurial skills for all learners; and
- Encourage learners to learn a Ghanaian language and a modern foreign language as part of becoming a global citizen.

2.4 Philosophy and Objectives of Biology Education

The philosophy and objectives of biology education in Ghana are grounded in the belief that scientific literacy and competency are essential for individuals to make informed decisions, address complex challenges, and contribute to societal progress.

Key objectives of biology education in Ghana include:

- Appreciation of biodiversity: Students should develop an understanding and appreciation for the diversity of living organisms.

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- Understanding of biological structures and functions: Students should gain knowledge of the structure and functions of living things at different levels of organization.
- Development of scientific problem-solving skills: Students should learn to apply scientific approaches to solving personal, societal, environmental, economic, and health problems.
- Acquisition of practical skills: Students should develop the practical skills needed to work with scientific equipment, biological materials, and living organisms.
- Data analysis and interpretation: Students should be able to collect, analyze, and interpret biological data and present it graphically.
- Interdisciplinary understanding: Students should recognize the connections between biology and other scientific disciplines.
- Lifelong learning: Students should develop a sustained interest in studying biology and continue to learn throughout their lives.
- Environmental awareness: Students should appreciate and understand the interrelationships between organisms and their environment.
- Social responsibility: Students should recognize the value of biology to society and use their knowledge responsibly.
- Critical thinking and creativity: Students should develop a sense of curiosity, creativity, and critical thinking.

2.5 Problems of Teaching and Learning Biology in Ghana Senior Secondary Schools

One of Ghana's advancements is based on science and its use in the workplace and business. A solid understanding of science and mathematics is necessary for competent

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workers and citizens in general (Anamuah-Mensah, 2004). Therefore, a firm foundation in science and technology serves as the currency for nations' social and economic development (Anamuah-Mensah, 2004). The science curriculum is not what it seems to be, despite the fact that on paper it looks to be wonderful. According to research by Barke, Nyarko, and Klecha (2011), just a small percentage of Ghana's youth roughly 44 percent of the country's total population are scientifically literate, and the adult figure is significantly lower.

According to Nwagbo (2005), education in the sciences, particularly biology, is widely acknowledged as a means of fostering economic growth, eradicating poverty, and establishing social welfare. Although developing nations like Ghana, Nigeria, and others have worked to expand the availability of biology education at the secondary and higher education levels, the teaching and learning that is now taking place in Ghana's biology classrooms appears deficient as a result of a number of difficulties.

The quality and methods of teaching in the field of Biology have been a subject of concern. Ayodele (2006) identified the predominant use of inappropriate and ineffective teaching methods as a major factor hindering students' comprehension and success in science, particularly in Biology. Tordzro et al. (2012) emphasized that the teaching and learning of Biology should move beyond theoretical and lecture-based approaches.

However, despite these recommendations, several studies, including Abubakar (2017), and Musa (2017), have highlighted that many Biology teachers tend to employ expository teaching methods. These methods often present Biology as an abstract subject, disregarding the diverse interests and varying levels of ability among students within the classroom. Consequently, Biology lessons are perceived as unengaging, and students struggle to grasp fundamental scientific concepts, skills, and principles,

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resulting in subpar academic performance. Zubairu (2016) supported this perspective by emphasizing the need for teachers to consider students' varying interests and abilities when delivering Biology instruction to enhance understanding and engagement.

Content Relevance and Relatability are critical aspects of effective education. Olanrewaju (2012) defines relevance as the extent to which learning experiences hold value for students in various contexts, including their career aspirations, the study of different subjects, and their understanding of events in their immediate surroundings. Relatability, on the other hand, refers to the students' capacity to connect their classroom experiences in biology with their everyday lives.

One of the challenges students often face in studying biology is the perceived gap between what is taught in biology classes and its relevance to their daily experiences, as highlighted by Cimer (2012). According to Olanrewaju (2012), this disconnection can lead to student demotivation, loss of interest, and the development of a negative attitude toward the subject. Consequently, the subpar performance of students in Biology can be attributed to their limited ability to relate to the subject matter and the perception that some of the concepts are irrelevant.

Concerns about teacher competency and readiness are very important in the setting of science education. The appropriateness of teacher training and its compatibility with the curriculum is one crucial problem. Due to their poor scientific expertise, many science teachers struggle to convey scientific concepts clearly. Olanrewaju (2012) noted that biology teachers' specialization can frequently leave them unprepared to teach particular biology subjects. For instance, biology instructors with a PGDE in education and a background in zoology could. Ibrahim (2015) also drew attention to the fact that some biology teachers find it difficult to teach subjects like ecology, genetics, and

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evolution because they did not receive enough exposure to these fields in their undergraduate studies. A lack of clarity in conveying scientific concepts is the result of this weak scientific foundation. And it difficult to explain principles relating to botany. The lack of qualified science teachers has a detrimental effect on both the teaching and learning of science, according to Brobbey, Baah, and Ampon-Wireko (2020). It is clear that some science teachers' methods of instruction do not correspond to the objectives of Ghana's scientific curriculum. These problems highlight how crucial it is to increase teacher support and training in order to raise the standard of science instruction in the nation.

Inadequate Instructional Materials and Teaching Facilities: According to Ahorlu (2013), inadequate instructional materials are a major contributing factor to poor performance of students in biology. Wada (2016) noted that many Senior Secondary Schools in Nigeria do not have standard Biology laboratories and enough teaching and learning materials. As a result, the teachers do not carry out Biology lessons as expected and students find the subject difficult to learning. In addition, lack of teaching and learning resources also militate against science teaching. Little or no practical work is done due to shortage of equipment and consumables, and the development of a scientific way of thinking is abandoned in favor of the learning of nomenclature, definitions and stock standard procedures (O'Connor, 2002).

Students' Poor Study Habits: According to Cimer (2012), students' study habit is one of the reasons they have difficulties learning Biology. Balbalosa (2010) stated that good study habits help learners in critical reflection and in skills such as selecting, analyzing, critiquing, and synthesizing which make them perform better than learners with poor study habits. However, Omorogbe and Ewansiha (2013) observed that many students

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do not study or review previously taught concepts on Biology examination questions on a regular basis. In addition, Abubakar (2017) noted that a good number of students also fail to listen attentively in class as they suddenly lose interest in what their instructors are saying. This might result from the teacher's style of teaching; the nature of topic being taught or the students' negative attitude to Biology. This is corroborated by Koballa and Glynn (2007) when they stated that the "approaches to positively affecting student attitudes include instructions that emphasize active learning and the relevance of science to daily life" (p. 95). Serwaa-Ampaafo (2017) also noted that in many Ghanaian Senior Secondary Schools, Biology practical work is ill-conceived among many students as unproductive.

Nature and Cost of Biology Textbooks: Mohidiu (2008) observed that Biology textbooks are often found to consist of long and complex sentences that are laden with facts. Such structural complexities impose considerable cognitive demands on students. Lebata (2014) pointed out that Biology contains many technical terms in describing its concepts, principles and theories, and is therefore more susceptible to reading difficulties than other natural sciences. Many technical terms are derived from Latin and Greek words which are alien to the learners. According to Amoah et al., (2023) the lack of the textbooks has made education more expensive for pupils in public schools since the provision of books have been left to "education business individuals". Zubairu (2016) added that the high cost of Biology textbooks is another factor that could be responsible for students' poor performance. The recommended Biology textbooks cost a fortune and most parents can hardly afford to purchase these textbooks since Biology is not the only subject that students do in school. Library facilities in schools where students who cannot afford the needed Biology textbooks can borrow such books are grossly inadequate and the and the services are unsatisfactory. Thus, without textbooks

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to complement and supplement classroom instruction, students are handicapped and come hardly prepared for the WASSCE.

2.6 Students' Academic Performance in Biology at Senior Secondary Schools

Academic performance is commonly defined as a comprehensive assessment of students' achievement in a particular test or examination after a period of instruction and learning, typically quantified as a numerical score (Lawal, 2009).

Another perspective, offered by Obeka, Bichi, and Yusuf (2012), characterizes academic performance as the demonstration of knowledge acquired or skills developed in school subjects, as determined by test and examination scores or grades assigned by subject teachers.

It is essential to recognize that academic performance holds significance when the teaching and evaluation of students encompass all three major domains of educational objectives: cognitive, affective, and psychomotor domains. In other words, a holistic assessment of academic performance takes into account not only cognitive knowledge but also emotional and practical skills acquired during the educational process

Lebata (2014) specifically pointed out the prevalence of low performance in science subjects, notably Biology, in several African countries, including Ghana, Lesotho, Nigeria, and Uganda. This trend has contributed to a widely acknowledged decline in the standard of science education in these nations. The collective findings of these researchers underscore the global challenge of addressing and improving student performance in science, particularly in the critical area of Biology at the senior secondary school level.

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

However, Lawal (2010) observed that a number of reasons have been identified as being responsible for the high failure rate in Biology, prominent among which include the teachers' use of inappropriate teaching methods, overloaded Biology syllabus, difficulty of topics and some concepts as well as absence of dedication and resourcefulness on the part of the teachers. Lebata (2014) although admitted that Biology performance in WASSCE is the poorest among all other science subjects, but in a broader perspective attributed the poor performance in science subjects to poor quality of science teachers whose methods of teaching such as excessive talking, writing of notes and rote learning of textual materials tend to inhibit interest; the

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prevalent exposition method of instruction rather than inquiry, with very little involvement of learners in experimentation; and shortage of laboratory facilities and equipment necessary for practical work. Hence, to help improve students' performance in these final examinations, Biology and by extension, science, need to be taught effectively. The teachers need to employ methods that will enable the students to learn more, retain more and apply what is learnt by engaging in significant and appealing activities. The Biological Sciences Curriculum Study (BSCS) 5Es Problem Solving Model, according to Ibrahim (2015) and Umahaba (2016), offers a promising opportunity in this respect.

Nonetheless, with the lingering poor performance of students in Biology, a vast amount of research has been conducted on different groups of students using novel and innovative instructional strategies to see if perhaps the situation can be remedied. The results of most of these researches appear to be promising. For instance, (Owusu, 2016) worked on improving the performance of students in Adeiso SHS in the teaching of photosynthesis through the use of activity method and found that students exposed to conceptual change strategy performed significantly better than those taught with the traditional method. Likewise, the work of Appaw (2011) on comparing concept mapping and traditional methods in teaching selected topics in biology at the senior high achievement, retention and attitude of secondary school Biology students with varied abilities showed that there was significant difference in the performance of students taught with concept mapping and those taught using the traditional methods of teaching. Lakpini (2012) on the effects of conceptual change instructional strategy on achievement, retention and attitude of secondary school Biology students with varied abilities showed that there was no significant difference in the performance of average ability subjects taught using conceptual change instructional strategy and high ability

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group subjects taught using traditional method. The findings also revealed that low ability subjects exposed to conceptual change strategy performed significantly better than average ability subjects taught using traditional method and subjects of low ability exposed to conceptual change strategy performed significantly better than low ability subjects exposed to traditional method.

Ibrahim (2012) conducted a study to explore how different levels of verbal interaction between teachers and students affected the academic performance of senior secondary school Biology students. The research discovered that students who were taught Biology with a high level of teacher-student verbal interaction achieved significantly better results in certain Biology concepts compared to those exposed to medium or low levels of interaction. Science education emphasizes hands-on practical work as a way for learners to develop scientific literacy in order to meet global challenges (Millar, 2004). Therefore, the teaching of biology should prioritize student-centered and activity-based approaches, with the teacher serving as a facilitator, as advocated by Asare (2010).

According to, several studies have found that the 5Es Learning Cycle Model (LCM) had a positive impact on students' performance in physics. Vincent, Cassel, and Milligan (2008) found that the 5E LCM is effective in enhancing students' understanding of mass, density, and volume. Wilson, Tranter, & Devereux (2010) found that the group instructed via inquiry-based 5E model had a greater level of achievement compared to the group instructed via commonplace instructional method. Hokkanen (2011) found that the 5E model can enhance learner interest, academic performance, and confidence in science when employed correctly with devotion and loyalty. Madu and Amaechi (2012) found that the 5Es LCM had a positive impact on pupils'

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perceptions of elasticity. According to the meta-analysis study conducted by Ferdi Bahadir and Melih Dikmen (2022), the 5E learning model has an excellent effect on academic achievement. The overall effect size value calculated at the 95% confidence interval was determined as 0.997, indicating that teaching based on the 5E model increased academic achievement compared to traditional teaching.

In addition, Ihejiamaizu and Ochui (2016) affirmed from their findings on the utilization of Biology laboratory equipment and students' academic performance in Cross River State, Nigeria that utilization of Biology laboratory equipment significantly influenced students' academic performance in Biology. Therefore, the results obtained from these studies collectively imply that a strategy which is student-centered, collaborative, where students are actively involved in knowledge construction has positive influence on students' performance and helps to increase their ability to apply knowledge acquired to solve real life problems.

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

2.7 Trends of Senior Secondary Students' Performance in Photosynthesis Concepts

Researchers across the world like Kumasah (2022), Etobro & Fabinu (2017), Cimer (2012), Serwaa-Ampaafo (2017), Buah and Akuffo (2017) and Chatila and Al-Husseiny (2017) have studied students' difficulties in learning Biology and have shown that senior secondary school students either perceive most of the photosynthesis concepts as difficult and so have difficulty in learning them. Tekkaya, Özkan, & Sungur (2001) highlighted that Turkish high school students and teachers found several concepts

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challenging, including mitosis and meiosis, protein synthesis, respiration, photosynthesis, organic and inorganic molecules, as well as diffusion and osmosis. Similarly, Fauzi & Mitalistiani (2018) reported that Genetics, Metabolism, and Immune System were the most three difficult Biology topics for the students. In 1987, Haslam and Treagust conducted a study that explored the misconceptions of Australian students aged 13 to 17. The aim of their research was to develop a two-tier diagnostic tool to accurately assess secondary students' understanding of photosynthesis and respiration in plants. The results indicated that a high percentage of secondary school students do not comprehend the nature and function of plant respiration and have little understanding of the relationship between photosynthesis and respiration in plants. Özay and Öztas (2003) used a questionnaire with seven open-ended questions to investigate the misconceptions of Turkish students aged 14 to 15, obtaining results similar to those of previous studies. The authors propose that these misconceptions are influenced by the school curriculum. Students have, as general rule, individual knowledge about plants, photosynthesis, respiration, chemical processes in plant but they cannot associate this knowledge into one coherent complex.

More objectively, WAEC Chief Examiner's Reports (2009-2018) highlight a number of photosynthesis concepts as being unpopular and least attempt and if attempted, often failed among candidates. The report also states candidates wrote the equation of respiration instead of the equation of respiration.

WAEC (2013) mentions that candidates were able to define photosynthesis but were unable to give balanced equations and list the external and internal factors that affect the rate of photosynthesis. In addition, many candidates could not list and explain the products of the light dependent stage of photosynthesis.

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Many candidates according to the report were also writing about photosynthesis instead of giving the structures and stating the functions of each structure as required. One can thus deduce from the above literature that photosynthesis concepts are of high perceived difficulty in the senior high school Biology syllabus.

The gravity of this issue is highlighted by Çimer (2012), Agboghoroma and Oyovwi (2015), and Chatila and Al-Husseiny (2017), who acknowledge that the difficulty of biology topics has a substantial impact on students' motivation and academic success. Çimer (2012) states that because of this worry, researchers are looking at the causes of students' biological issues and potential solutions. Many researchers have found a number of factors that contribute to pupils having trouble studying biology, including Özay and Öztas (2003), Asare (2010), Amoah et al. (2023), Owusu (2019), and Azure (2015). These include the complex nature of biological sciences, the teaching methods, techniques, and styles used by biology educators, the abstract and interdisciplinary nature of biological concepts, the quantity of events, topics, and facts students must learn, overloaded biology curricula that might not be directly applicable to real-world applications, the lack of discussions on topics of student interest, teachers neglecting student expectations, and the segregation of biological science education from other disciplines. Together, these explanations highlight the numerous difficulties students experience when learning biology.

However, Çimer (2012) summarizes it by saying that knowing how secondary school students feel about biology would aid decision-makers in planning more effective lessons that will improve students' grasp of biology and their attitudes toward it.

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2.8 Science Process-Skills Acquisition among Senior Secondary School Students

As explained by Karamustafaoglu (2011), the concept of science process skills typically pertains to the abilities or competencies that scientists need during the process of scientific exploration. These skills can be categorized into two main groups: basic and integrated process skills. The basic process skills encompass activities such as observation, inquiry, classification, measurement, and prediction. Integrated process skills include, identifying and defining variables, interpreting data, manipulating materials, recording data, formulating hypotheses, designing investigations, making inferences and generalizations. Njoku (2002) provided a definition of science process skills as cognitive and psychomotor abilities utilized in the process of problem-solving. These skills are what scientists rely on when they identify issues, conduct impartial research, gather data, manipulate it, interpret findings, and communicate their results. They represent the aspects of scientific learning that remain intact even when cognitive knowledge has faded, and they can be acquired and enhanced through training, particularly through participation in practical science activities. Science process skills (SPS) play a crucial role in enabling students to explore their surroundings and construct their own understanding throughout the learning journey (Athuman, 2017). When students engage in inquiry-based learning activities, such as experiments, hands-on tasks, and discussions, they are provided with opportunities to independently construct meaning from their experiences (Chebii, Wachanga, & Kiboss, 2012; Mulyeni, Jamaris, & Supriyati 2019). These activities encourage active participation, critical thinking, and problem-solving, which are central to the development of deeper understanding in science education. These activities empower students to formulate and test hypotheses, collect and analyze data, make observations, and draw conclusions (Aydoğdu, 2014). Through these inquiry-based activities, which encompass scientific

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process skills, students can shape their own perceptions of the world around them. Consequently, the incorporation of SPS into the teaching and learning process simplifies and makes chemistry education more relevant.

According to Kazeni (2005), the American Association for the Advancement of Science (AAAS) was the pioneer in identifying the activities that constitute science process skills. Kazeni asserts that the AAAS delineated science processes into fourteen tasks or abilities, categorized based on operational challenges and cognitive requirements. These abilities are further classified into two groups: basic science process skills and integrated science process skills.

The basic science process skills, as outlined by AAAS, encompass observing, measuring, inferring, classifying, predicting, and communication. On the other hand, the integrated science process skills include formulating hypotheses, identifying variables, defining variables operationally, designing investigations, experimenting, analyzing data, indicating cause and effect relationships, and formulating variables/models.

Enebechi (2008) acknowledges that over the years, various authors and researchers have proposed modifications to the list of science process skills. However, the list established by the AAAS is noted to remain comprehensive in its form.

Research such as those of Wang, (2023), Santos, Carvalho, Pedro & Ferreira (2023), Şimşek and Kabapınar (2010), Abungu, Orodho and Ochieng (2014), Okere and Wachanga (2014), Jack (2018) and Duniya, Olorukooba, Usman and Obeka (2016) have shown that participating in inquiry-based activities in science classrooms at all educational levels helps students to realize the science process skills. Teachers are the

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most successful in helping students learn science process skills, thus they must develop these abilities to the necessary levels (Karamustafaoglu, 2011). Teachers should employ student-centered techniques and involve students in activities that will help them build their science process skills in order to help learners acquire these skills (Gurses, Cetinkaya, Dogar, and Sahin, 2015). According to Padilla (1990) teachers must give students diverse opportunities and ample time to develop and engage with these abilities in various curriculum areas and contexts if they are to learn science of process skills.

2.9 Relevance of Science Process-Skills to Science Education

The development of students' scientific process skills (SPS) is a focal point in the chemistry curricula of various nations. Specifically, in Turkey, nurturing students' SPS is regarded as a priority within the chemistry curriculum, enabling students to address practical, real-world issues (Aydm, 2013). Similarly, the chemistry curriculum in Nigeria incorporates SPS to instill real-life applications in students (Jack, 2018). Likewise, the chemistry subject curriculum in Tanzania, as outlined by the Ministry of Education and Vocational Training (MoEVT) in 2010, places significant emphasis on fostering students' SPS. This emphasis is grounded in the recognition of the vital role that SPS play in advancing scientific knowledge and enhancing an individual's life.

By allowing students to investigate the environment and build their own meaning during the learning process, the science-process skills positively enhance cognitive and critical thinking skills (Athuman, 2017). Based on findings from numerous studies, Ozgelen (2012) noted that there is a positive correlation between the development of science process skills and the conceptual framework of the cognitive domain, which includes information processing skills, reasoning skills, inquiry skills, creative thinking skills, and problem-solving skills. According to Chebii et al. (2012) and Mulyeni et al.

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(2019), students can create meaning for themselves when they participate in exploratory inquiry learning activities such as discussions, experiments, and hands-on activities. These activities give students the opportunity to develop and test hypotheses, collect and analyze data, make observations, and draw conclusions (Aydodu, 2015). Therefore, it is believed that people who have learned and use science process skills will be able to handle complicated cognitive obstacles and think clearly and coherently when confronted with intellectually puzzling issues—all of which are necessary for making crucial decisions. Students develop their own meaning about the world around them through these inquiry activities, which are scientific process skills.

According to NARST (2014), the scientific method, which forms the bedrock of scientific research and is primarily concerned with solving specific problems, relies heavily on the application of science process skills. Similarly, Rehorek (2004) observed that the development of science process abilities empowers students to design and address issues within research laboratories effectively. Furthermore, science process skills (SPS) are not limited to students alone; scientists also rely on them extensively in their research endeavors. Abungu et al. (2014) and Aydodu (2015) highlight SPS as essential research techniques for scientists. In their work, researchers identify problems, formulate theories, and conduct studies that encompass data collection, analysis, interpretation, as well as the identification and control of variables (Abungu et al., 2014). To make sense of their findings and draw meaningful conclusions, students and researchers alike may employ data visualization techniques, including graphs, tables, phrases, and diagrams, as noted by Yadav and Mishra (2013). These tools aid in conveying complex information effectively.

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Science process skills also play a pivotal role in fostering scientific creativity among students. Scientific creativity, as defined by Dass (2004), is the ability of an individual to identify gaps in a problem or in available information, generate ideas or hypotheses, test and refine these hypotheses, and communicate the resulting data. Aktamis and Ergin (2008) observe that this definition bears similarities to that of science process skills, as both are driven by the need to address real-life problems. Therefore, creativity can be considered a crucial component of scientific skill. To reinforce this notion, Aktamis and Ergin (2008) conducted a study aimed at examining the impact of teaching science process skills on students' scientific creativity, attitudes toward science, and academic achievement. This research underscores the interconnectedness of science process skills and scientific creativity, highlighting how the development of these skills can enhance students' ability to think creatively and effectively solve scientific problems in their daily lives. The study mentioned revealed that scientific process skills education led to increased student achievement and enhanced scientific creativity. However, it did not result in significant improvements in students' attitudes toward science when compared to the teacher-centered method. Given these findings, the current study aims to investigate whether the adoption of the 5Es Problem-Solving Model can influence the acquisition of science process skills, knowledge retention, and the performance of secondary school biology students. This research seeks to assess whether this particular instructional approach can have a positive impact on students' development of science process skills, their ability to retain knowledge, and their overall academic performance in the subject of biology.

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2.10 Instructional Strategies in the Teaching and Learning of Biology

According to (Gitlin, Smyth, & Schifter, 1984; Posner, 1985, & Biott, 1983) instructional strategies refer to the methods and activities used to facilitate learning and teaching. These strategies can range from very detailed and precise steps associated with particular strategies to more general discussions of the use of particular strategies. According to Shaibu (2008), it is a process of imparting, transferring, or sharing knowledge that eventually results in observable and preferable behavioral changes in the individual.

Different techniques or methodologies are currently available for teaching biology concepts, and the choice of one depends on the particular knowledge, abilities, and attitudes that need to be imparted.

Some of the methods identified by Ezeaghasi (2014), Hofstein and Lunetta, 2004, and Gamo (2023) for teaching Biology concepts include the Laboratory Method, Lecture Method, Role-playing Demonstration Method, Discussion Method, Discovery Method, Enquiry Method, and Field Trip Method, among others. These are discussed in details below:

i. **Laboratory Activity Method**: This is a method of teaching where by tools, apparatus and instructional materials are used to stimulate and enhance the process of learning in a place known as the laboratory. As noted by Hofstein & Lunetta, 2004, the laboratory method involves hands-on experiments where students engage in active exploration to understand scientific concepts. This method enhances practical skills like observation, data collection, and critical analysis. For example, students studying biology may analyze slides under a microscope to learn about cellular structures. Ugwoke (2023) highlights that the

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laboratory method is essential in teaching biology as it allows students to engage directly with biological concepts through experimentation and observation. This method is particularly effective in enhancing students' practical skills and scientific understanding by bridging theoretical knowledge with real-world applications. Laboratory work according to Shuaibu (2017) also strengthens theoretical knowledge, the development of their psychomotor skills as well as pleasure of discovery. It increases creative thinking skills, higher order thinking skills and the development of manual dexterity by the use of tools and equipment, allowing students to apply skills instead of just memorizing facts.

ii. **Lecture Method**: It involves a one-way communication pattern in which the teacher is the dominant figure and students' participation is virtually non-existent, rather they listen, ask questions and take notes. This is a method used primarily to introduce students to a new subject, but it is also a valuable method of summarizing ideas, showing relationships between theories and practice and reemphasizing the main points. Gamo (2023) emphasizes that this traditional method of teaching is efficient for delivering structured and detailed content, particularly in large classroom settings. However, Gamo notes that traditional lectures often fail to maintain student engagement, leading to passive learning. According to Abubakar (2017), a lecture can be an effective method for communicating theories, ideas and facts to students. Mani (2008) postulated that if Lecture Method is to be used, it should be applied on matured groups of students who can jot down points during instruction and a list of reference books should be provided by the instructor to help students read further and make notes on their own. McFarland (2020) emphasizes the effectiveness of lectures for delivering foundational knowledge, particularly in contexts where the primary

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goal is to impart theories, models, or frameworks that students can later engage with in more applied settings. Additionally, research by French & O'Leary (2020) underscores that while lectures are highly efficient in transferring information, the method's success often hinges on how well teachers connect with students and present the material in a structured and engaging manner. Without incorporating interactive elements, such as discussions or formative assessments, students may struggle with retention and critical thinking skills (Spicer-Escalante & deJonge-Kannan, 2016)

iii. **Demonstration Method**: The demonstration method of teaching involves the instructor actively showing students how to carry out a task or explain a concept. This method focuses on visual learning, where the teacher provides a step-by-step model of the process, allowing students to observe and grasp the procedure before attempting it themselves (Sweeder & Jeffery, 2013; Price & Brooks, 2012). By witnessing the demonstration, students can better understand abstract concepts and gain practical insights into how the task should be completed, enhancing their learning experience. Price and Brooks (2012) suggests that the demonstration method boosts academic performance in both practical and theoretical assessments, while Tamari, Bonney, and Polizzotto (2015) found that students performed better on tasks involving demonstrations compared to those without. Obeka (2010) noted that it is a method where by the teacher illustrates concepts with hands-on activities and relevant examples. When students learn through Demonstration Method, they concretize learning and the comprehension lasts longer (Ezeaghasi, 2014).

iv. **Discussion Method**: According to EduCorpus (2024), the discussion method is important for teachers as it fosters critical thinking skills, develops

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communication skills, encourages active participation, and promotes community building within the classroom. The discussion method of teaching is a dynamic, student-centered approach where both the teacher and students actively participate in dialogue about a specific topic. This approach is designed to stimulate critical thinking, foster collaboration, and facilitate the exchange of ideas. The teacher's role is primarily to guide the conversation, encouraging students to contribute their insights and perspectives. This process aims to deepen understanding by promoting exploration of diverse viewpoints, addressing uncertainties, and enhancing problem-solving abilities (Black, 2021; Elliott, 2019). The discussion method, Obeka (2013) emphasizes several key strategies for the teacher to ensure effective learning outcomes. Firstly, the teacher should select a topic that aligns with the students' interests, ensuring it is both engaging and provocative, prompting critical thought and debate. Additionally, assigning roles to participants can enhance engagement and structure during the discussion. It is crucial for the teacher to plan the type of discussion in advance, whether it is a formal debate, small-group discussion, or a more open-ended conversation. The teacher should also provide clear guidance to ensure the discussion remains focused on the topic at hand, while actively motivating students to stay engaged and attentive throughout. Finally, the teacher should foster an environment where students feel comfortable asking questions to clarify any uncertainties they may have.

v. **Discovery Method**: Yousafzai (2022) describes the discovery method as a student-centered approach that stresses problem-solving, critical thinking, and inquiry-based learning. This method allows students to actively participate in their learning process by investigating topics through inquiry and exploration.

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Discovering learning involves presenting pupils with information in a form which requires them to discern relationships within the information and to structure and make sense of the information and relationship. Gallenstein (2004) posited that discovery is essential as students are actively involved in the process of learning and topics are intrinsically motivating. Mirzoyan (2023), also highlighted that discovery-based learning encourages students to actively explore concepts, develop critical thinking, and problem-solving skills. Teachers act as facilitators, guiding and supporting students as they make their own discoveries.

vi. **Enquiry Method**: The inquiry method is a structured, student-centered process where learners engage in questioning, investigating, and constructing their understanding of a topic. The method integrates collaboration, active research, and reflection, encouraging critical thinking and information literacy. Teachers guide students through a framework of inquiry phases: initiating, exploring, investigating, creating, sharing, and evaluating. This process supports meaningful learning by connecting curriculum goals with students' interests and experiences. Mani (2008) observed that this method has different names given to it by different scholars such as Problem Solving, Critical Thinking, Reflective Inquiry and Inductive Thinking. Mahuta (2013) stated that Discovery Method provides the opportunity for the learners to seek knowledge in a systematic and logical way as well as provide the students with the opportunity to examine ideas, events and problems about a particular concept or situation. Inquiry-based learning (IBL) has been shown to significantly enhance student engagement and motivation by allowing learners to delve into areas of personal interest. This approach fosters a sense of ownership over their educational journey and

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nurtures intrinsic motivation, which in turn strengthens their commitment to academic tasks. Such effects are particularly pronounced in environments where student-driven questioning forms the foundation of classroom activities, creating an engaging and interactive learning atmosphere (Cents-Boonstra, Lichtwarck-Aschoff, Lunenberg, & Wegerif, 2020; Polman & Scornavacco, 2022). According to Polman and Scornavacco (2022), In inquiry-based classrooms, students' questions and curiosities drive classroom activity and provide purpose for their work on a daily basis and across time. Teachers challenge students to learn to work independently, as well as collaboratively during their inquiries. Students collaborate with one another on separate and shared inquiries through talk, interaction and discussion, and spend time creating products or performances, sharing them with various audiences. Inquiry also allows students to take action to contribute meaningfully to their communities.

In summary, it is crucial for this study to utilize a method that effectively enhances the acquisition of science process skills, academic performance, and knowledge retention among students. As highlighted by Jack (2017), the BSCS 5Es Problem-Solving Model is a promising strategy for achieving these objectives.

2.11 The Concept of 5Es Instructional Model

Modified from the SCIS (Science Curriculum Improvement Study) learning cycle presented by Atkin and Karplus (1967) in the 1960's, the 5E instructional model was developed in the late 1980's as a component of the Science for Life and Living curriculum created through the Biological Sciences Curriculum Study (BSCS) (Bybee & Landes, 1990). According to Bybee (1997) the work of German philosopher Johann

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Friedrich Herbart, in addition to that of John Dewey and Jean Piaget also influenced this model (p. 168), which has been modified over time to include 3E, 4E, and 7E variations. Given the input of such influential contributors to educational research, it should be no surprise that the 5E model is rooted in constructivism and is supported by research that addresses methods for conceptual change (Bybee & Landes, 1990). The 5Es instructional model according to Erickson and Verstynen (2017) describes a teaching sequence that helps students build their own understanding from experiences and new ideas and can be used for entire programs, specific units and individual lessons.

According to Özmen (2004), the 5 Es Learning Cycle Model (LCM) is the best applied model of the constructivist learning scheme (Bybee et al., 2006). This model depends upon the concept that students are necessary to build their own information about novice ideas and knowledge through examining, exploring, testing, and purifying their earlier outlooks and opinions. During experiential learning, the students practice concepts and realities instead of mere hearing. Positive alterations occur in outlooks, knowledge, abilities, interest and rational of the students. What amount of learning occurs mainly depends upon the quality of experience (McElhane, 1998). This model is frequently utilized within the paradigm of science education (Soomro, Qaisrani, Rawat, & Mughal, 2010) and can be utilized for all subjects. Through the utilization of this model, the learner can learn supplementary knowledge about science content, science process and critical thinking skills (Buntod, Suksringham & Singseevo, 2010; Yalcin & Bayrakceken, 2010). According to Bybee and Landes (1990), “the objective in a constructivist program is often to challenge students’ current conceptions by providing data that conflict with students’ current thinking or experiences that provide an alternate way of thinking about objects and phenomena” (p. 96). The 5Es learning model stimulates the scholars’ interest and creativity (Rasul, Shahzad & Iqbal, 2019).

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According to the National Institute of Health (NIH, 2017), this model is an inquiry-based learning cycle that sequentially arranges learning events to give students the chance to develop their conceptual understanding over time. By "inquiry," we mean that the model has a structure built in for fostering an active, collaborative, and constructivist classroom where students are not just listening and reading but also developing skills, analyzing and evaluating evidence, engaging in experiences and discussions, sharing their own understanding with their peers, and planning investigations and problems together.

This learning model comprised of events that are necessary to develop learners' interest in research, reply to their subject related expectations and contain the effective utilization of their information and skills (Ergin, 2006). It is comprised of the five stages namely: engagement, exploration, explanation, elaboration, and evaluation (Carin & Bass, 2000 and Lorsbach, 2006).

In the 5Es instructional model, each element is carefully designed to facilitate the construction of students' knowledge and understanding. It's important to note that evaluation is not confined to the final phase of the learning cycle; instead, it is integrated into all four phases.

The engagement phase serves as the starting point, where prior knowledge is accessed through short activities that capture learners' interest and motivation. During this phase, students personally connect with the topic and the learning activity, establishing relationships between educational practices. Teachers introduce a question, problem, or scenario, encouraging learners to discuss the subject and identify their existing knowledge. This step, as outlined by Bybee (1997) and Wilder & Shuttleworth (2005),

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sparks learners' curiosity and sets the foundation for the subsequent phases of exploration, explanation, elaboration, and evaluation in the learning cycle.

Students are given a shared set of tasks throughout exploration experiences, which allows for the identification of present concepts (such as misconceptions), processes, and skills as well as the facilitation of conceptual change. Students can complete lab exercises that enable them to draw on existing knowledge to develop fresh concepts, ponder issues and options, and plan and carry out a pilot study. The instructor guides and provides the necessary material to make the learners responsive (Newby, 2004; Carin & Bass, 2000).

The essence of the explanation phase lies in the objective to "present concepts, processes, or skills briefly, simply, clearly, and directly" (Bybee, 1997, p. 180). Consequently, the teacher's role becomes crucial during this phase as they guide students in understanding the connections between their own interpretations and formal scientific phenomena. Various instructional strategies, including the use of videos, software, and literature, are employed to support this process. In the initial stage, students are prompted to offer their explanations derived from events explored during the exploration phase. Following this, the formal language of science is introduced (Bybee, 1997). Beyond simply expressing their own thoughts, students are encouraged to actively listen to and question the explanations provided by their peers. This interactive process contributes to the enhancement of their individual learning experiences.

During the elaboration stage, students apply their newly acquired knowledge to different situations. This phase involves a more in-depth study of concepts, enabling

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students to discover additional relationships and nuances. The lesson culminates at this stage with a confirmation of student understanding.

At the elaboration stage, students deepen and broaden their knowledge and understanding. They go beyond the initial grasp of concepts and begin to apply the acquired knowledge. Instructors encourage learners to use their newfound knowledge in diverse and novel situations, fostering a sense of responsibility (Morse, Roberts, Szesze, & Wayne, 2004). This phase promotes a deeper integration of knowledge and the development of practical skills as students engage with the subject matter in more complex contexts.

In line with effective instructional methods, there comes a stage where the understanding of concepts by students needs to be assessed, and in the 5E model, this is the evaluation phase. While some form of informal evaluation takes place throughout the inquiry process, the evaluation phase specifically involves formal assessment (Bybee, 1997). It's important to note that this assessment doesn't take the form of a typical multiple-choice test. On the contrary, evaluation in the 5E model includes open-ended questions, demonstrations, and often involves probing questions that guide students into the next phase of inquiry.

What sets the evaluation in the 5E model apart is the inclusion of the student's opportunity to assess their own understanding and growth in relation to the concept. This self-evaluation component distinguishes the 5E model from other types of assessment (Bybee, 1997). It encourages students to reflect on their learning journey, fostering a deeper understanding of the material and promoting a sense of ownership over their educational progress.

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2.12 5Es Instructional Model and Academic Performance and Retention in Biology

Numerous studies, including those by Ajayi and Osoko (2013), Akinmade (1997), Kwarteng (2016), Serwaa (2007), and Abubakar (2017), and WAEC (2010–2018), have documented the persistent and subpar academic performance of Ghanaian students in science subjects, particularly Biology at WASSCE. Researchers have given a number of causes for this, including the continued use of the Lecture Method, which is teacher-centered, authoritative, unstable, ineffective, and unproductive for biology teaching and learning in the twenty-first century. As per Moyer, Hackett, and Everett (2007), a significant number of students today engage in passive learning within classrooms where teachers primarily organize and present the material to the class. Otami (2009) and Osoko (2013) have observed that the teaching of science in secondary schools' places heavy emphasis on content. Many science teachers, according to these studies, tend to prefer traditional expository or 'chalk and talk' methods. This preference leads them to avoid more activity-oriented teaching strategies, such as the inquiry method, discovery method, cooperative learning strategies, problem-solving strategies, and investigatory laboratory approaches, which are more student-centered. As a result, there is a pattern toward abstraction in science classrooms as a result of the rejection of and unwillingness to adopt activity-oriented educational approaches. Due to this, kids are now less actively engaged in the learning process and are more likely to memorize facts by heart, which has a negative impact on their academic performance. Additionally, this method has caused students to lose interest in biology and to adopt a negative attitude about the topic. However, according to Opara (2011), to potentially enhance students' academic performance in Biology, there is a need to shift from the traditional classroom

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practices commonly experienced in the classrooms. Instead, there should be a move towards more inquiry-based teaching practices that facilitate meaningful learning.

The 5 Es Learning Cycle Model (LCM) according to Özmen (2004), is the best applied model of the constructivist learning scheme (Bybee et al., 2006). This model depends upon the concept that students are necessary to build their own information about novice ideas and knowledge through examining, exploring, testing, and purifying their earlier outlooks and opinions. It demands a high level of interaction among the learner, teacher, the content or area of study, available resources, and the learning environment. In the 5Es learning cycle instruction, students are given the opportunity to describe objects and events, pose questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others.

Numerous research studies have been conducted to assess the effectiveness of the 5Es instructional model in facilitating the learning of Biology concepts and its impact on the academic performance of students in both secondary and tertiary institutions.

A study conducted by Yılmaz and Demirci (2021) found that the 5E model significantly improved students' understanding of complex biology topics, particularly in the areas of genetics and ecology. The inquiry-based structure of the 5E model encourages deeper engagement with content, which leads to better conceptual clarity and application of knowledge in new contexts. Students were able to make connections between theoretical knowledge and real-world applications more effectively compared to traditional methods.

A study by Mahmud and Jalal (2021) found that students taught using the 5E model retained biology concepts for a longer period compared to those who received

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traditional instruction. The retention rates were particularly higher for experimental groups in topics such as cell biology and genetics, demonstrating the long-lasting effects of inquiry-based learning.

Research by Ceylan and Gültekin (2023) emphasizes that the 5E model enhances students' motivation and self-efficacy in biology. The model's emphasis on student-led inquiry and hands-on exploration fosters a sense of ownership over learning, which motivates students to engage more deeply with the content. As a result, students reported feeling more confident in their ability to grasp challenging biology concepts. This increased self-efficacy was linked to improved academic performance, especially in areas that traditionally pose challenges for students, such as molecular biology and physiology.

A study by Karataş and Özdemir (2022) demonstrated that students taught using the 5E model showed significant improvement in their ability to design experiments, hypothesize, and analyze data. These skills are essential for mastering biology, as they are aligned with the scientific method. By engaging in the "explore" and "explain" phases of the cycle, students enhanced their problem-solving abilities, which in turn improved their performance on both formative and summative assessments.

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CHAPTER THREE

METHODOLOGY

3.0. Overview

This chapter outlines methodology employed to investigates the impact of 5Es Problem-Solving Instructional Model on science process-skills acquisition, performance and retention in photosynthesis among high school Biology students in Akroso SHTS. The chapter is structured into several key sections that detail the research design, population, sampling techniques, instrumentation, and treatment administration.

3.1 Research Design

This study made use of a quasi-experimental design using a pre and post-test approach involving both control and experimental groups. Quasi-experimental research offers the benefit of comparing the two groups (control and treatment) based on naturally occurring treatment groups (Cohen, Manion and Morrison., 2018). As noted by (Best & Kahn, 2014), this design is particularly suitable for classroom-based research as it does not require randomization of participants. In this study two groups were used: an experimental and a control group. The experimental group and the control group were two intact classes from the same school that were purposefully chosen. Specifically, Class B was the control group and Class A was the experimental group. Both groups (experimental and group) were given a pre-test to determine equivalency and to evaluate the students' initial skill levels and academic performance in photosynthesis. The Experimental Group was taught the concept of photosynthesis using 5Es Instructional Model, whereas the Control Group was taught the same concept using Conventional Method for four (4) weeks. Following treatment, both groups were given

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a post-test to examine the impact of the two instructional methodologies on students' science process-skills development and academic performance in photosynthesis. A post-posttest was given two weeks later to assess students' retention abilities. Normal classes hours were used in order not to disrupt school organization.

3.2 Population of the Study

The target population for this study comprises of the two public Senior High Schools form two elective Biology Students in Asene-Manso-Akroso district in Eastern Region-Ghana. The schools offer Biology as an elective science subject.

The accessible population was made up of one hundred and twelve (112) SHS form 2 elective Biology students. This accessible population were selected from two intact classes from Akroso Senior High Technical School in Asene Manso Akroso district to form the sample.

3.3 Sample and Sampling Techniques

The sample for the study comprised of 112 students (74 females and 38 males) from two pre-existing classes at Akroso Senior High Technical School. Each class had students who were already grouped for regular academic purposes.

The researcher used a coin-flip method to assign one class as Class A (Experimental Group) and the other as Class B (Control Group). Mugenda and Mugenda (2003) suggest that a minimum of 30 students per class is required for quasi-experimental research. The experimental group consists of 56 students (35 females and 21 males), while the control group has 56 students (39 females and 17 males). The sample size in this study also aligns with the Central Limit Theorem, as recommended by Sambo (2008), which advises a minimum of 30 students per group for studies of this kind.

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3.4 Instrumentation

Two instruments were used in this study for data collection. The instruments are:

1. Science Process Skills Acquisition Test (SPSAT);
2. Photosynthesis Performance Test (PhPT);

3.4.1 Science Process-Skill Acquisition Test (SPSAT)

There were thirty (30) alternative-to-practical items on the SPSAT, which included multiple choice, graphing, sketching, short-answer, and item-completion questions. The purpose of the SPSAT was to assess students' mastery of the six (6) fundamental science process skills: measurement, observation, classification, communication, inference, and prediction. Details of items contained in the pretest and post-test/post-post-test this instrument are presented in Appendix C and Appendix E respectively. The marking scheme for both the pretest and post-test are presented in Appendix I and Appendix H respectively.

3.4.2 Photosynthesis Performance Test (PhPT)

This test instrument comprised forty multiple-choice items designed to evaluate students' understanding of photosynthesis. Previous WASSCE Biology questions were used to create the performance exam. The concepts covered in the Senior High School Biology curriculum's section on photosynthesis served as the basis for the questions. The multiple-choice item format was used because **a)** it allows for a wider coverage of the contents, **b)** is normally free of bias in marking, **c)** its ability to provide for adequate sampling, **d)** its ability to provide for good item pool. There were four options (A–D) in the items; one was the right response, while the others were just distractors. As to Bloom's (1975) taxonomy, the examination items corresponded to the five cognitive levels.

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Table 1: Table of Specification for PhPT based on Bloom's Taxonomy

Level	Questions	Count	Percentage
Remember (Knowledge)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 16, 20, 31, 32, 33, 35, 36, 37, 39	21	52.5%
Understand (Comprehension)	11, 13, 21, 22, 25, 28, 29, 34, 38	9	22.5%
Apply (Application)	14, 17, 19, 23, 24, 26, 40	7	17.5%
Analyze (Analysis)	18, 27	2	5.0%
Evaluate (Evaluation)	30	1	2.5%

Table 1 shows that a total of 40 questions from PhPT span the five Bloom (1975) cognitive levels: Remember (52.5%), Understand (22.5%), Apply (17.5%), Analyze (5%), Evaluate (2.5%). Details of the items contained in pretest and posttest/post-postest of PhPT are presented in Appendix B and Appendix D respectively. The marking scheme for the pretest and posttest are presented in Appendix F and Appendix G respectively.

3.5 5Es Instructional Package (5-EIP)

The 5-EIP, or 5Es Instructional Model Protocol, is the teaching approach that was used to cover the topic of photosynthesis over the course of four lessons. The researcher personally developed these lessons, which followed the five distinct phases of the 5Es Instructional Model as originally described by Bybee and colleagues in their 2006 publication. By adhering to this model, the lessons aim to provide a structured and effective learning experience for students, guiding them through the process of understanding the complex concept of photosynthesis. These phases included engage, explore, explain, elaborate and evaluate. The package was meant to guide the treatment

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of the experimental group by the researcher. The teaching package consisted of five individual lessons, each designed to be activity-based and cover a specific topic related to photosynthesis.

Every lesson is created to fit within a two-hour time frame, which is equivalent to a double period in a typical school schedule. The package is structured to be taught over the course of four weeks, with one topic being covered per week. This allows for a comprehensive exploration of photosynthesis, giving students ample time to engage with the material and participate in the designed activities. In developing these lessons, the researcher carefully considered and aligned the content and learning objectives with those outlined in the Senior High School Biology curriculum. This ensures that the lessons not only effectively taught the concept of photosynthesis but also met the educational standards set for this level of study. The 5Es instructional model is presented in Appendix O.

3.6 Validity of the instruments

According to Fraenkel, Wallen, and Hyun (2012), validity refers to the defensibility of the interferences that may arise as a result of using an instrument for data collection. As much as possible these inferences must be corrected to permit the instruments to collate valid conclusions about the characteristics under study. For that matter, the face and content validity of the instruments were confirmed.

3.6.1 Face Validity

The determination of face validity was geared towards ensuring that items developed in the test was devoid of ambiguity. The correct frame of sentences and the length of questions and scenarios used were valid as much as possible. The instrument was be given to 2 lecturers, 3 post-graduate colleagues, 3 biology teachers and a supervisor to

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establish the face validity of the instruments. After scrutiny of the test instruments' corrections, suggestions and adjustments were taken into consideration and the resultant changes were made where necessary to ensure they are valid as much as possible.

3.6.2 Content Validity

An instrument demonstrates content validity when it reflects fairly, and comprehensively covers the domain or items that it is intended to cover (Cohen, Manion and Morrison, 2007). Fraenkel, Wallen and Hyun, (2012) posit that content validity refers to the appropriateness of the content, its comprehensiveness, how it logically gets at the intended variable, and the suitability of the items in the content in representing what is to be accessed. To determine the content validity, Fraenkel, et al. (2012) suggested that, "someone" who can run an intelligent judgment about the adequacy of the instrument should be used to validate the content of the instruments used. Therefore, to determine how valid the items in the content of the various instruments the study's supervisor subjected the instruments to critical scrutiny based on the UEW professional teaching standards. After the scrutiny, the supervisor declared the contents of the instruments valid for the data it sought to collect.

3.7 Pilot testing

The test instrument was piloted on 35 form two SHS students at Atweaman SHS in Asene Manso Akroso district which is not part of the study sample but part of the target population sample for the study. The Pilot testing was conducted so as to determine the reliability of the instruments, the appropriate time frame the student might need in responding to the questions. The pilot testing was also conducted to help identify any

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problems that may arise during the actual study when administering the instrument. This helped identify any potential issues for clarity and accuracy.

The SPSAT had 30 alternative-to-practical test items, but the PhPT, which originally had 50 multiple-choice questions, were given to the form two biology students by the researcher. The researcher, read directions on how to answer the questions to the students. Students were also allowed to seek clarification. The researcher allocated different time frames for the SPSAT and PhPT examinations. Students were given one (1) hour and forty-five (45) minutes to complete the SPSAT, while one (1) hour and fifteen (15) minutes was set aside for the PhPT. This scheduling was designed to provide students with ample time to approach the questions thoughtfully and without undue pressure. Any problems or challenges encountered during the pilot testing period were meticulously documented. The data gathered was utilized to improve and refine the final assessment instrument. Following each test, the researcher collected all question papers and answer sheets from the participants. These were then graded using a marking scheme, which were developed to maintain fairness and consistency in the evaluation process.

3.8 Reliability of the instruments

Results of the SPSAT and PhPT from the pilot testing were analysed to determine the reliability and internal consistency of the instruments.

- **SPSAT**: in determining the reliability of the SPSAT, test-retest method was used. The interval for the conduction of the test and retest was two weeks. In assessing the reliability of the test-retest and the degree with the two sets of scores are consistent across the two administration of the test, Pearson Moment Correlation statistics was used. The reliability coefficient (r) of SPSAT was

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found to be 0.83 which indicates a high coefficient of stability of the instrument. The test-retest reliability analysis of SPSAT is presented in Appendix N. The internal consistency of reliability of the SPSAT test was found to be high, with a Cronbach's alpha of 0.90. This indicates that SPSAT has a strong coefficient of internal consistency and is therefore reliable for use in this study. The Cronbach's Alpha reliability analysis of SPSAT is presented in Appendix J.

- **PhPT**: In determining the reliability of the PhPT, test-retest method was used. The interval for the conduction of the test and retest was two weeks. In assessing the reliability of the test-retest and the degree with which the two sets of scores are consistent across the two administration of the test, Pearson Moment Correlation statistics was used. The reliability coefficient (r) of PhPT was found to be 0.84 which indicates a high coefficient of stability of the instrument. The test-retest reliability analysis of PhPT is presented in Appendix K. The internal consistency of reliability of the test was found to be high, with a Cronbach's alpha of 0.91. This indicates that PhPT has a strong coefficient of internal consistency and is therefore reliable for use in this study. The Cronbach's Alpha reliability analysis of PhPT is presented in Appendix L.

3.9 Item Analysis

During the pilot study, data were collected to enable item analysis. This data was used to calculate the facility and discrimination indexes for each test item in the PhPT.

3.9.1 Facility index

The Facility index describes the overall difficulty of the questions, representing the ratio of users that answer the question(s) correctly. In principle, a very low (≤ 5% or 0.05) or very high (≥ 95% or 0.95) facility index suggests that the question is not useful as an instrument of measurement (Blanco & Ginovart, 2010).

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The facility index is basically a percentage score ranging from 0% to 100% (i.e. from 0 to 1) The higher the facility index, the easier that test question was.

According to Miller, Linn and Gronlund (2009), you want facility indices in that middle range - not too easy, not too hard. Items scoring between 30% - 70% (0.3 - 0.7) tend to be the best at separating the high achievers from the low achievers and giving you useful data to evaluate what students have learned. In this study, test items with facility indices from 30-70% or 0.3 - 0.7 were considered moderate and were therefore accepted for use as recommended by Usman (2008). Details of facility indices of PhPT items are presented in Appendix M.

3.9.2 Discrimination index

The discrimination index measures how well a specific test question distinguishes between strong and weak pupils. It examines the association between how students scored on that specific item and their overall test performance.

An effective question is one that the test's top scorers tended to get right but the lower scorers missed. That suggests the question did an adequate job of distinguishing between more competent and less able students (Ibrahim, 2015).

In this study, facility index and discrimination index were used to assess a question's ability to differentiate between proficient and weak learners. For this study the index of discrimination for the PhPT fell within 0.30-0.8 implying that the instrument is suitable for the study. The discrimination indices of PhPT test items are presented in Appendix M.

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3.10 How treatment was administered

The treatment administered to the subjects involved teaching the concept of photosynthesis by the researcher to both the experimental and control groups for four (4) weeks. The experimental group was exposed to the 5Es Instructional Package (5-EIP) while the control group was taught using Conventional Lecture Method.

3.10.1 Pre-treatment stage

At this stage, a pretest was administered to both groups (Experimental group and Control group) to determine their equivalence in terms of process-skills acquisition and academic performance in Photosynthesis. The results from the pretest were subjected to an independent Sample t-test analysis. The results from the analysis showed that both groups were statistically homogeneous, and that any changes found later in the post-test findings can be attributed to the intervention rather than pre-existing differences in students.

3.10.2 Treatment of the Experimental Group

The experimental group was divided into 7 sub-groups containing 8 students each. Each sub-group consisted of male and female students of different ability levels. The rationale behind grouping the students in that way was in threefold.

First, it allowed for more productive interaction and collaboration among the students within each group. Having them work together in smaller teams rather than as one huge class tends to facilitate better engagement and participation.

Secondly, dividing them into mixed groups helped neutralize any potential gender-based differences or imbalances that could skew the results if the groups were segregated by gender.

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And finally, from a practical management perspective, breaking the full class into smaller groups made it easier for the researcher to oversee and handle an appropriately sized number of students in each section. Regular classrooms and sometimes the biology laboratory was used for the lessons. The treatment was based on the BSCS 5Es Instructional Model which is an inquiry-based teaching approach (Llewellyn, 2005). The 5Es Instructional Model provides a structured approach for facilitating the learning process in a way that allows students to build their own understanding of concepts. The model guides students through five sequential phases, each represented by a word starting with **'E**':

First is the **Engagement phase**, where students' interest and curiosity about the topic are piqued through thought-provoking questions, activities or scenarios. This phase provides an opportunity for the teacher to find out what students already know or think they know about the topic and concepts to be developed.

This leads into the **Exploration phase**, giving students hands-on opportunities to investigate the concepts through experiments, small group discussions, research or problem-solving activities. During this stage, they work together to make observations and gather data.

The **Explanation phase** follows, where students analyze their findings, draw conclusions, and instructors provide clarity by directly explaining the target concepts and addressing misconceptions. The instructor can also bring in formal language and scientific terms, as well as information that could help students explain their previous experiences more easily.

Students then move into the **Elaboration phase**, applying what they've learned to new situations through additional activities, labs or real-world examples to solidify and

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extend their understanding. This stage aids students in linking new experiences with previous ones, integrating ideas, and enhancing their comprehension of concepts and processes.

Finally, the **Evaluation phase** allows instructors to assess students' grasp of the concepts through quizzes, presentations or other performance-based methods to identify areas of mastery or needed review.

In essence, the 5Es model provides an inquiry-based learning cycle that engages learners' natural curiosity, guides them through exploring and discovering core ideas, and culminates in articulating and demonstrating their conceptual understanding.

The flowchart for the 5Es Instructional Model is presented in Figure 2.

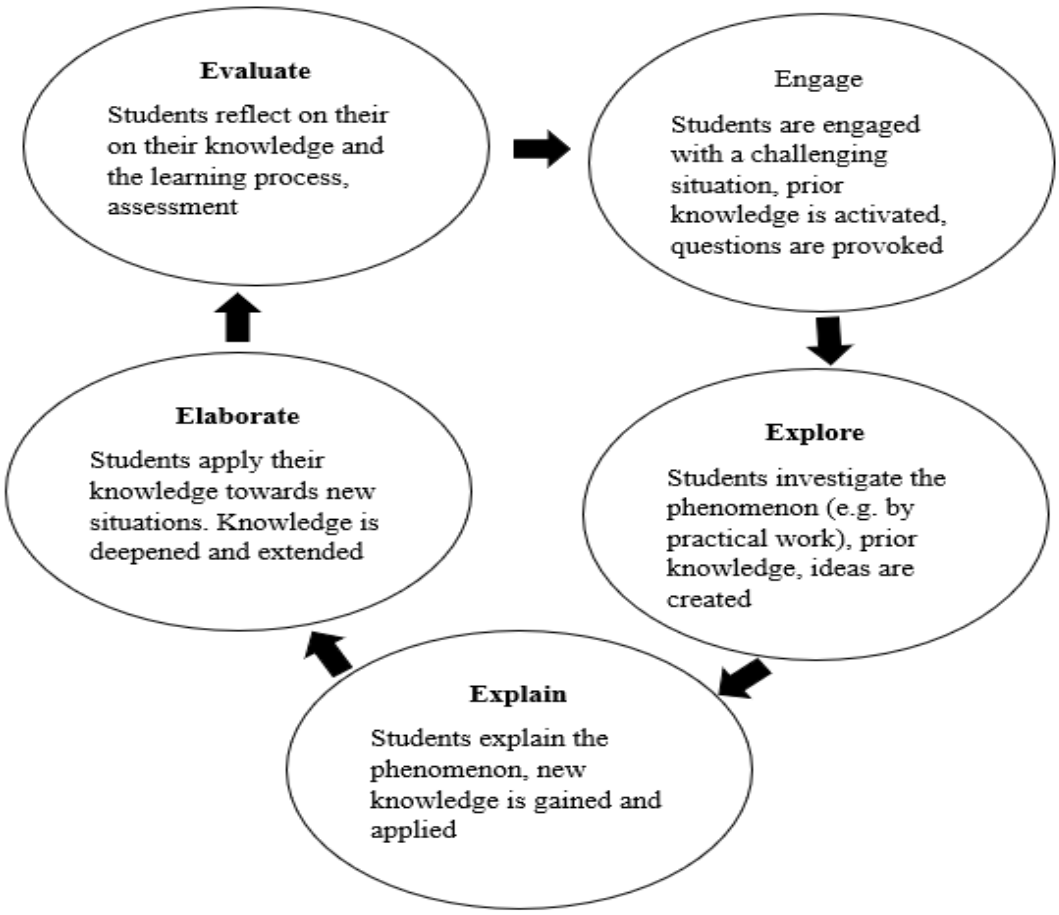

Figure 2: Flowchart Illustrating the 5Es Instructional Model

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3.10.3 Teaching the Control Group

The key points regarding the Conventional Method used for the control group are:

1. The control group received instruction on all subtopics related to photosynthesis from the teacher for four weeks.
2. The duration of each lesson was two hours, equal to that of the experimental group.
3. The teaching approach followed the Conventional Method, where the researcher verbally presented the content to the students.
4. Visual aids such as whiteboards and charts displayed on cardboard papers were used.
5. Students were expected to actively listen to the teacher and take notes during the lessons.
6. The researcher allowed students to ask questions intermittently, but the focus was on the teacher's delivery of the content.
7. At the end of each lesson, students received assignments or notes to reinforce the concepts covered.
8. The lesson plans developed for the control group were validated by the researcher's supervisor to ensure alignment with the conventional teaching approach.

The Conventional Method used for the control group primarily centered on the teacher delivering the content verbally, with limited student interaction or activity beyond note-taking and occasional questions. The visual aids used were traditional tools like whiteboards and charts on cardboard papers.

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3.11 Approach to Gathering Data

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

i. **Science Process-Skills Acquisition Test (SPSAT)**: This test had a maximum possible score of 70 points. The researcher came up with a grading scheme to score the tests accurately.

   Once the tests were graded, the scores were sorted into two groups: the experimental group and the control group. Within each of those groups, the scores were further divided by the students' gender – male or female. The researcher then used a statistical software called SPSS version 27.0 to analyze all the test scores he had collected and sorted. He had two main goals with this analysis.

   First, he wanted to see if the experimental group performed better or worse on the test compared to the control group. In other words, did the different teaching methods lead to different levels of learning?

   Secondly, the researcher wanted to look specifically at the experimental group's scores and see if there were any differences between how the male and female students performed. Was there any gender-based patterns in how well the new teaching approach worked?

ii. **Photosynthesis Performance Test (PhPT)**: Two separate tests were administered to evaluate the students' comprehension and retention of the photosynthesis concepts. The first test, a post-test, was given immediately after the conclusion of the four-week treatment period. The second test, a post-posttest, was administered two weeks after the initial post-test. Both of these

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tests had a maximum achievable score of 40 points, and a predetermined marking scheme was used to grade them accurately.

The primary objectives of these analyses were twofold. Firstly, to determine if there existed a significant difference in academic performance and retention of photosynthesis concepts between the experimental group, which received the new teaching approach, and the control group, which received the conventional teaching method. Secondly, the analyses aimed to investigate whether there was any discernible gender-based disparities in academic performance and retention within the experimental group, which could potentially indicate the efficacy or limitations of the new teaching approach for different genders.

3.12 Data Analysis Approach

The data gathered from this study served two primary objectives through the following procedures:

i. **Addressing the Research Questions**: To answer the research questions that informed the study's direction, statistical measures such as means, standard deviations, and mean differences between students' pre-test and post-test scores were calculated and analyzed using SPSS.

ii. **Testing the Null Hypotheses**: The collected data was also used to evaluate the null hypotheses formulated for the study. These hypotheses were tested using the Independent Samples t-test, with a significance level set at $p < 0.05$, which is a commonly accepted threshold in research.

3.13 Ethical Standards

The headmistress of the school was informed about the study's purpose, methodology and its potential impact. Consent was given by the head of the institution. Before the

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study commenced, informed consent was obtained from all participants and their guardians. Students and guardians were provided with detailed information about the study's purpose, procedures, potential risks, and benefits, ensuring that participation was voluntary and based on a full understanding of the study's aims aligning with the ethical principle of informed consent emphasized by (BERA, 2018). Measures were taken to safeguard participants' identities and the confidentiality of their data. Names and any identifying information were removed from the data to maintain anonymity. Data was securely stored and accessible only to authorized individuals directly involved in the research to prevent unauthorized access or misuse. This was to ensure protecting the data and also confidentiality (Resnik, 2020). The study design aimed to minimize any potential harm to participants. Activities and assessments were designed within the scope of regular academic requirements to avoid undue stress, and participants were informed of their right to withdraw from the study at any time without any negative consequences. Both the experimental and control groups were treated equitably. While the instructional approaches varied, all students received the same academic content and support, with the control group taught via the conventional method. This ensured no participant was disadvantaged in their learning experience due to the study. At the study’s conclusion, participants were debriefed about the research’s findings and how their involvement contributed to educational insights. This transparency helped students and their guardians understand the broader significance of their participation and the study’s potential contributions to educational. This ethical approach not only safeguards the participants but also enhances the reliability and applicability of the research findings, potentially contributing to meaningful advancements in educational practice and policy.

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CHAPTER FOUR

RESULTS ANALYSIS AND DISCUSSION

4.0 Overview

This study looked at how well secondary school biology students performed academically, retained information, and were able to use science process skills, particularly when it came to photosynthesis while using the 5Es Instructional Model in place of more conventional teaching techniques. Data was collected using the Science Process-Skills Acquisition Test (SPSAT) and the Photosynthesis Performance Test (PhPT). The findings presented in this section were gathered from a sample of 112 biology elective students at Akroso SHTS, located in the Eastern Region of Ghana's Asene Manso Akroso district. Six research questions and six research hypotheses served as the study's compass.

4.1 Biodata of Participants

Participant of this research work were Form two elective biology students in Akroso Senior High Technical School. Two intact classes were used for the research work. Each of the two classes which were later classified as Experimental group and control group had 56 participants. In all 112 students participated in the research. Table 2 indicate the frequency and distribution of gender in the two classes.

Table 2: Frequency and Distribution of Gender of Participants.

Class Name	Group	Male	Female	Total
Class A	Experimental	21	35	56
Class B	Control	17	39	56
Total		39	73	112

Source: Field Data, 2024

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Table 2 shows that out of the fifty-six (56) students which formed the experimental group, 21 of them which constitutes 37.5% were males and 35 representing 62.5% were females. Also from Table 2, 17 of the 56 students representing 30.4% were males and 39 of the control group representing 69.6% were females. The experimental group were taught the concept of photosynthesis using 5E's instructional model, while the control was also taught photosynthesis using the traditional lecture approach.

4.2 Research Question one

What is the difference between the mean academic performance scores of senior high school Biology students taught photosynthesis using 5Es Instructional Model and those taught the same concept using Conventional Method?

This research question sought to find out whether the 5Es instructional model used in teaching would yield significant results on the academic performance of biology students taught photosynthesis using 5Es instructional Model and students taught the same concept using the conventional method (lecture method). In light of this, both the experimental group and the control group were a given a pre-test to the determine their performance in photosynthesis in biology before any intervention. In order to address this question, the null hypothesis one ($H0_1$): *''There is no statistically significant difference between the mean academic performance scores of secondary school Biology students taught photosynthesis using 5Es Instructional Model and those taught the same concept using Conventional Method''* was tested. The means and standard deviations of the students' pre-test of PhPT scores in the experimental and control groups, as well as the mean differences between them, were calculated. The outcome is shown in Table 3.

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Table 3: Independent Sample t-test of the Mean Pre-test PhPT score for Experimental and Control Group

Group	N	Mean	SD	Df	t-cal	p-value	Remarks
Experimental	56	18.64	3.961	110	0.204	0.839	Not
Control	56	18.50	3.443				significant

Significant at $p \leq 0.05$

Table 3 shows a preliminary analysis of the pretest score of the two classes that is the experimental group and control group. This analysis was carried out to determine their preliminary competence levels in photosynthesis and also to identify potential similarities or differences between the two classes prior to when the treatment was given. Table 3 shows the experimental group having a mean score of 18.64 and the control group having a mean score of 18.50, giving a mean difference between the two groups to be 0.14. From Table 3, the t-value was 0.204, while the p-value is 0.839. And since the p-value (0.839) is greater than the significance level of 0.05 there is no significant difference between the mean PhPT score of students in the experimental group and those in the control group. This implies that the two groups had statistically similar initial knowledge in photosynthesis. This homogeneity ensures that any changes found later in the post-test findings can be attributed to the intervention rather than pre-existing differences in students.

After the pre-test, the experimental group were taught the concept of photosynthesis using 5E's instructional model whilst the control group were taught the same concept using the traditional method. After a period of four (4) weeks, a post-test on the concept of photosynthesis was conducted to assess the academic performance of both the Experimental group and the control group under WAEC examination condition. The post-test mean PhPT scores of the students in the experimental and control groups were

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analyzed using independent Sample t-test statistics and a summary of the analyses is presented in the Table 4.

Table 4: Independent Samples t-test of Mean Posttest PhPT Scores for Experimental and Control Groups

Group	N	Mean	SD	Df	t-cal	p-value	Remarks
Experimental	56	23.89	1.83	110	15.26	0.001	Significant
Control	56	15.68	3.58				

Significant at $p \leq 0.05$

Table 4 presents the post-test PhPT scores of students in both the experimental and control groups, focusing on their academic performance in photosynthesis. The experimental group, which was taught using the 5Es Instructional Model, had a mean score of 23.89 with a standard deviation of 1.83. In contrast, the control group, taught using conventional methods, had a lower mean score of 15.68 with a standard deviation of 3.583. With 110 degrees of freedom, the calculated t-value was 15.26 while the p-value was 0.001 at a level of significance of 0.05. Since this p-value is less than the 0.05 significance level, we reject the null hypothesis and conclude that there is a significant difference in the mean academic performance scores between students taught with the 5Es Instructional Model and those taught with the Conventional Method. The 5Es Instructional Model seems to lead to higher academic performance scores than the Conventional Method.

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4.3 Research Question two

What is the difference in the mean Science Process-Skills Acquisition scores of secondary school Biology students taught photosynthesis using the 5Es Instructional Model and those taught the same concept using Conventional Method?

The research question sought to find out whether educational intervention in the form of 5Es Instructional Model would yield significant results on the science process-skills acquisition scores of the sampled students that participated in the research. In the light of this, both groups were given a pre-test to determine their science process-skills in photosynthesis in biology before any intervention. In order to address this question, a null hypothesis($H0_2$) ''*There is no statistically significant difference between the mean science process-skills acquisition scores of secondary school Biology students taught photosynthesis using 5Es Instructional Model and those taught the same concept using Conventional Method''* was tested. Table 5 below shows the results of the student's performance in the pre-test.

Table 5: Independent Samples t-test of Pre-test Mean Scores for Experimental and Control Group

Group	N	Mean	SD	Df	t-cal	p-value	Remaks
Experimental	56	13.70	2.515	110	0.123	0.903	Not
Control	56	13.64	2.084				Significant

Significant at $p \leq 0.05$

Table 5 shows a preliminary analysis of the pretest score of the two classes, that is, the experimental group and control group. This analysis was carried out to determine their preliminary competence levels in science process-skills and also to identify potential similarities or differences between the two classes prior to when the treatment was

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given. Table 5 shows the experimental group having a mean score of 13.70 and the control group having a mean score of 13.64, giving a mean difference between the two groups to be 0.06. From the Table 5, the t-value was 0.123, while the p-value is 0.903. And since the p-value (0.903) is greater than the significance level of 0.05, there is no significant difference between the mean score of students in the experimental group and those in the control group. This implies that the two groups had statistically similar initial skills and knowledge in photosynthesis. This homogeneity ensures that any changes found later in the post-test findings can be attributed to the intervention rather than pre-existing differences in students.

After the pre-test, the experimental group were taught the concept of photosynthesis using 5E's instructional model whilst the control group were taught the same concept using the traditional method. After a period of four (4) weeks, a post-test on the concept of photosynthesis was conducted to assess the science process-skills of both the Experimental group and the control group under WAEC examination condition. The post-test SPSAT scores of the students in the experimental and control groups were analyzed using independent Sample t-test statistics and a summary of the analyses is presented in the Table 6.

Table 6: Independent Samples t-test of Mean Posttest SPSAT Scores for Experimental and Control Group

Group	N	Mean	SD	Df	t-cal	p-value	Remaks
Experimental	56	58.82	8.86	110	10.67	0.001	Significant
Control	56	38.80	10.88				

Significant at $p \leq 0.05$

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Table 6 reports t-value of 10.67 and a p-value of 0.001 observed at a degree of freedom of 110 is well below the significance level of 0.05. This indicates that the difference in mean science process-skills acquisition scores between the experimental and control groups is statistically significant. Given the significant p-value, the null hypothesis ($H0_2$), which posited that there would be no significant difference between the mean scores of the two groups, is rejected. Enforcing the conclusion that the 5Es Instructional Model is more effective in fostering science process skills among secondary school Biology students than conventional teaching methods.

4.4 Research Question three

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

This research question sought to find out whether the 5Es instructional model used in teaching photosynthesis would yield significant results on the science process-skills acquisition scores of males and females' students. In order to answer the question, the null hypothesis($H0_3$) *''There is no significant difference between the mean science process-skills acquisition scores of male and female secondary school Biology students taught photosynthesis using 5Es Instructional Model''* was tested. The posttest SPSAT scores of male and female students in the experimental group were analysed and a summary of the analysis is presented in Table 7.

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Table 7: Mean and Standard Deviation Statistics of Posttest SPSAT Scores for Male and Female Students in the Experimental Group.

Group	N	Post-test Mean	Standard Deviation
Male	21	58.43	6.787
Female	35	50.51	9.745
Mean difference		7.92	

Significant at $p \leq 0.05$

Table 7 presents data comparing the posttest Science Process-Skills Acquisition Test (SPSAT) scores of male and female secondary school Biology students who were taught photosynthesis using the 5Es Instructional Model. The mean posttest score for male students is 58.43, while for female students, it is 50.51. This indicates that, on average, male students scored higher than female students in the posttest. The standard deviation for male students is 6.787, and for female students, it is 9.745. The higher standard deviation for female students suggests greater variability in their posttest scores compared to male students. The mean difference between male and female students' scores is 7.92, with male students outperforming female students.

A t-test analysis was carried out using information from Table 7 and the results are captured under Table 8.

Table 8: Independent Samples t-test of Mean Posttest SPSAT Scores for Male and Female Students in Experimental Group.

Group	N	Mean	SD	Df	t-cal	P- value	Remarks
Male	21	58.43	6.78	54	3.27	0.002	significant
Female	35	50.51	9.74				

Significant at $p \leq 0.05$

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Table 8 shows a t-value of 3.27 and a p-value of 0.002 at degree of freedom of 54. The p-value is less than the 0.05 level of significance. This indicates that there is a significant difference between the mean post-test SPSAT scores of male and female students. Since the p-value (0.002) is less than the significance level (α=0.05), the null hypothesis is rejected. This suggests that the mean science process-skills acquisition scores differ significantly between male and female students taught using the 5Es Instructional Model.

4.5 Research Question four

What is the difference in the mean academic performance scores between male and female secondary school biology students taught photosynthesis using the 5Es Instructional Model?

This research question sought to find out whether the 5Es instructional model used in teaching would yield significant results on the academic performance of males and females' students.

To answer the question, null hypothesis four ($H0_4$): *''There is no statistically significant difference between the mean academic performance scores of male and female secondary school Biology students taught photosynthesis using 5Es Instructional Model''* was tested.

The means, standard deviations, and mean differences of posttest PhPT scores for male and female students in the experimental group were calculated and used. The results are presented in Table 9.

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Table 9: Mean and Standard Deviation of Post test PhPT scores for Male and Female students in the Experimental Group.

Group	N	Post-test Mean	SD
Male	21	23.90	1.670
Female	35	23.89	1.952
Mean difference		0.01	

The data in Table 9 provides a comparison of post-test academic performance scores (PhPT) for male and female students in the experimental group, who were taught using the 5Es Instructional Model. The post-test mean scores are nearly identical, with male students scoring 23.90 on average and female students scoring 23.89. The small standard deviations for both groups (1.670 for males and 1.952 for females) suggest that the scores for each gender are tightly clustered around their respective means, indicating consistency in performance

An Independent sample t- test was carried out using the information Table 9. The set alpha value for the analysis was set at $p \leq 0.05$. A summary of the analysis is presented in Table 10.

Table 10: Independent Samples t-test of Mean Posttest PhPT Scores for Male and Female Students in Experimental Group.

Group	N	Mean	SD	Df	t- cal	p-value	Remarks
Male	21	23.90	1.67	54	0.037	0.970	Not significant
Female	35	23.89	1.95				

Significant at $p \leq 0.05$

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The mean academic performance score for male students was 23.90, slightly higher than the mean score for female students, which was 23.89. A t-value of 0.037 at 54 degrees of freedom gave a p-value of 0.970. The p-value of 0.970 is greater than the significance level of 0.05, indicating that there is no significant difference between the mean academic performance scores of male and female students. Therefore, we fail to reject the null hypothesis meaning the mean academic performance scores for male and female students taught with the 5Es Instructional Model are not significantly different.

4.6 Research Question five

What is the difference in the mean retention scores between secondary school biology students taught photosynthesis using the 5Es Instructional Model and those taught the same concept using the Conventional Method?

This research question sought to find out the difference in mean retention scores between students taught the concept of photosynthesis using the 5Es instructional model and students taught the same concept using the conventional method of teaching. To address this research question, the null hypothesis five ($H0_5$): *''There is no statistically significant difference between the mean retention scores of secondary school Biology students taught photosynthesis using 5Es Instructional Model and those taught the same concept using Conventional Method"* was tested.

The means, standard deviations, and mean differences of the post-posttest PhPT scores of students in the experimental and control groups were calculated and used to answer the research question. The results are presented in Table 11.

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Table 11: Mean and Standard Deviation of Posttest and Post-Posttest PhPT Scores for Students in Experimental and Control Groups

Group	N	Post-Posttest Mean	SD
Experimental	56	25.95	1.494
Control	56	15.05	3.030
Mean difference		10.90	

Table 11 shows the mean retention scores of students in both the experimental and control groups, measured using post-posttest PhPT scores. The experimental group, taught using the 5Es Instructional Model, had a mean score of 25.95 with a standard deviation of 1.494. In contrast, the control group, which was taught using conventional methods, had a significantly lower mean score of 15.05 with a standard deviation of 3.030. The mean difference between the two groups is 10.90, indicating that students in the experimental group retained the information significantly better than those in the control group.

Also, Independent Samples t-test statistic was used to analyze the post-posttest PhPT scores of students in the experimental and control groups and a summary of the analysis is presented Table 12.

Table 12: Independent Samples t-test of Mean Post-Posttest PhPT Scores for Experimental and Control Groups

Group	N	Mean	SD	Df	t- cal	p-value	Remarks
Experimental	56	25.95	1.49	110	24.13	0.001	Significant
Group	56	15.05	3.03				

Significant at $p \leq 0.05$

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Table 12 shows a t-cal of 24.23 and a p-value of 0.001 at degrees of freedom of 110. The mean retention scores of students taught photosynthesis using the 5Es Instructional Model and those taught using the Conventional Method differ significantly, as indicated by the p-value, which is less than the 0.05 level of significance. The experimental group that used the 5Es Instructional Model benefited from the difference that was noticed. Therefore, we reject the null hypothesis and conclude that there is a significant difference in the mean retention scores of secondary school Biology students taught photosynthesis using 5Es Instructional Model and those taught the same concept using Conventional Method. It can be concluded that the 5Es Instructional Model greatly outperforms the Conventional Method in improving secondary school biology students' retention of photosynthesis.

4.8 Summary of Major Findings

1. Students taught photosynthesis using the 5Es Instructional Model had significantly higher academic performance scores than those taught using conventional methods. This indicates the superior effectiveness of the 5Es Instructional Model in enhancing students' understanding of photosynthesis.
2. The study found that the 5Es Instructional Model significantly improved students' science process-skills acquisition and academic performance in photosynthesis compared to conventional teaching methods. This is evident from the higher post-test mean scores in the experimental group.
3. There was a significant difference in the science process-skills acquisition between male and female students taught using the 5Es Instructional Model, with male students generally outperforming female students.

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4. The 5Es Instructional Model also led to better retention of knowledge. Students in the experimental group retained more information over time compared to those in the control group, as evidenced by the higher post-posttest scores
5. Although there was a significant difference in science process-skills acquisition between male and female students, there was no significant difference in their academic performance when taught with the 5Es Instructional Model. This suggests that the model is equally effective in improving academic outcomes for both male and female students.

4.9 Discussion

Table 3 shows the pre-test academic performance scores for students in the experimental and control groups before the intervention. The experimental group had a mean score of 18.64, while the control group scored 18.50, resulting in a mean difference of 0.14. The t-calculated value is 0.204, with a p-value of 0.839. Since the p-value is much higher than the significance level of 0.05, the difference between the two groups is not statistically significant. By implication, both groups (experimental and control group) had statistically similar initial skills and knowledge in photosynthesis before the intervention was given. The absence of a significant difference ensures that any changes observed in the post-test results can be attributed to the teaching intervention (5Es Instructional Model versus conventional methods) rather than to pre-existing differences in the students' initial abilities.

Table 4 compares the post-test academic performance scores of students in the experimental group (taught using the 5Es Instructional Model) and the control group (taught using conventional methods). The results show a mean score of 23.89 for the experimental group and 15.68 for the control group. The t-calculated value (t-cal) is

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15.26, and the p-value is 0.001. Since the p-value (0.001) is less than the significance level of 0.05, the difference in mean scores between the two groups is statistically significant. This leads to the rejection of the null hypothesis ($H0_1$) that there is no significant difference in the mean academic performance scores of students taught using the 5Es Instructional Model and those taught using the conventional method.

Students exposed to the 5Es framework were provided with opportunities to observe, measure, document, and analyze data through investigative activities, unlike those who experienced the conventional teaching approach. The significant difference can further be attributed to the fact that the 5Es Instructional Model provides the opportunity for students in the experimental group to experience interactive learning wherein they communicate, infer and predict future occurrences from data collected while they explore materials. This result agrees with the work of Karsli and Ayas (2014) who observed that the 5E instructional model-based learning successfully enriches the students' knowledge and improves the science process skills. A study by Sen & Oskay (2017) found 5E inquiry learning methods effective for improvement of achievement as compared to lecture-based method. The findings of this study were also confirmed by Shaheen (2015), Abidi (2014), Hussain and Hussain (2013), Sasmaz-Oren and Sari, (2019), Pulate (2009), Siwawetkul (2018) that learners who were given instructions by using inquiry-based learning got higher score than those who were given instructions by using traditional method.

The findings in Table 5 presents the pre-test mean scores for the Science Process-Skills Acquisition Test (SPSAT) of students in both the experimental and control groups before any intervention. The experimental group recorded a mean score of 13.70, while the control group scored slightly lower at 13.64, resulting in a mean difference of 0.06.

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The t-calculated value (t-cal) was 0.123, and the p-value was 0.903. Since the p-value (0.903) is much greater than the significance level of 0.05, there is no statistically significant difference between the two groups' scores. This suggest that, statistically the experimental and control groups were similar in their initial science process skills related to photosynthesis before the intervention. Such initial similarity is critical for maintaining the validity of the experimental design, as it ensures that any observed differences in the post-test results can be attributed to the teaching intervention rather than pre-existing disparities between the groups.

Table 6 presents the post-test mean scores for the Science Process-Skills Acquisition Test (SPSAT) of students in the experimental and control groups. The experimental group, taught using the 5Es Instructional Model, had a mean score of 58.82 with a standard deviation of 8.86, while the control group, taught using the lecture method, had a mean score of 38.80 with a standard deviation of 10.88. Table 6 also shows a t-calculated value (t-cal) of 10.67, and the p-value of 0.001, which is far less than the alpha level of significance of 0.05. With a p-value (0.001) far less than the significance level of 0.05, there is a significant difference between the two groups in favour of the experimental group. The significantly higher mean score of the experimental group demonstrates that the 5Es Instructional Model is more effective at fostering science process skills than the traditional teaching method. The high t-value (10.67) and the p-value (0.001) confirm that the differences observed between the groups are not a result of random chance but a strong indication that the 5Es Model is more effective in enhancing students' science process skill. The results of this study provide empirical support for Senan's (2013) assertion that the 5Es Instructional Model fosters inquiry-based learning while also enhancing the development of critical skills such as science process skills, creative thinking, and problem-solving abilities, all of which are vital for

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cultivating an inquisitive mindset. The finding also provides support to the research findings of Annan, Mensah, and Asare (2019), Athuman (2017), Sharbu (2017), Ibrahim et al (2018) and Opara (2011) on the efficacy of inquiry-based teaching approaches in fostering science process-skills acquisition among students better than the traditional teaching approach.

Table 7 compares the post-test mean Science Process-Skills Acquisition Test (SPSAT) scores of male and female students in the experimental group who were taught photosynthesis using the 5Es Instructional Model. The mean score for male students was 58.43, with a standard deviation of 6.787, while female students scored a mean of 50.51, with a standard deviation of 9.745. The mean difference between male and female students was 7.92, with male students outperforming their female counterparts. Table 8 provides the t-test analysis of the post-test mean scores for male and female students in the experimental group, focusing on their performance in the Science Process-Skills Acquisition Test (SPSAT). The t-calculated value (t-cal) was 3.27, with a p-value of 0.002 at 54 degrees of freedom. Since the p-value (0.002) is less than the significance level of 0.05, the difference in mean scores between male and female students is statistically significant. The 5Es instructional model promotes active learning for all students, however, factors such as gender-based learning preferences, societal influences, and classroom dynamics may contribute to boys demonstrating higher performance in certain contexts.

This finding agrees with the research outcomes of Abungu, Okere and Wachanga (2014), Kashu (2014), Guevara (2015), Ghumdia et al (2016) and Widdina, Rochintaniwati and Rusyati (2018) who in their independent studies indicated the existence of gender differences in the mastery of science process skills in favour of

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boys. The finding in this present study is at variance with the work of Amedu (2015) and Nnenna (2018) who observed the effect of gender on the achievement of students in biology and found out that male students performed better than their female counterpart. However, this disagrees with the study of Filgon and Linu (2017), they discovered that female students performed better than their male counterparts. Amedu (2015) and Rabacal (2016) found no significant gender differences in the acquisition and mastery of science process skills. Okoye (2016) in her study "influence of gender and cognitive styles on students' achievement in Biology" found that gender and cognitive styles have no significant influence on achievement scores of students in Biology. Her work is not in consonance with this study in that there is significant influence of gender on achievement in Biology.

However, Abungu, Okere and Wachanga (2014), Omiko (2015) indicated the existence of gender differences in the mastery of science process skills in favour of boy. This report is in consonance with the findings of the present study in that he found that they found that there was a significant difference in the achievement of male and female students who are taught basic science.

The findings in Table 9 reveal the post-test academic performance scores (PhPT) of male and female students in the experimental group who were taught photosynthesis using the 5Es Instructional Model. The mean score for male students was 23.90, while female students scored a nearly identical mean of 23.89. The difference was however not significant as shown by the t-test analysis in Table 10. From Table 10, the t-test analysis of the post-test scores for male and female students reveals a t-calculated value (t-cal) of 0.037, with a p-value of 0.970, which is much greater than the significance level of 0.05. This indicates that the observed difference in mean scores between male

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and female students is not statistically significant. This indicates that male and female students taught the concept of photosynthesis using 5Es Instructional Model do not significantly differ in their mean academic performance scores.

By implication it can be said that the 5Es Instructional Model is gender-friendly as it equally the academic performance of male and female students exposed to it. This supports the idea that educational strategies can challenge long-held preconceptions about gender and academic aptitude by fostering an environment where both sexes can achieve equally well. This finding is consistent with the research conducted by Umahaba (2016), Fasuyi and Udeani (2022) who observed that, there was no significant effect of gender on students' achievement in Biology. The finding is also in line with that of Anaduaka and Okafor (2013) in which they reported that students' achievement towards mathematics was significantly independent of sex. However, it would appear to contradict the findings of Kashu (2014) who found that males performed better than females in a period of 5 years in Biology, Chemistry and Mathematics. In the research conducted by Amedu (2015), the impact of gender on students' achievement in biology using the jigsaw method indicated that male students outperformed their female counterparts. This finding contrasts with the results of this current study, which found no significant differences in academic performance between genders.

However, it aligns with Nnenna (2018), who similarly reported that male students achieved higher scores than their female peers in biology assessments. Conversely, Filgona et al. (2017) identified that female students performed better than males, suggesting a divergence in outcomes based on instructional methods or contextual factors.

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The results from Tables 11 and 12 reveal a significant difference in retention scores between students taught using the 5Es Instructional Model and those taught with conventional methods. Specifically, the experimental group exhibited a higher mean retention score of 25.95 compared to the control group who had a mean retention score of 15.05, with a substantial mean difference of 10.90. The t-value of 24.13 and p-value of 0.001, the difference is statistically significant at the 0.05 threshold. This outcome implies that the 5Es Instructional Model enhances retention capabilities more effectively than traditional teaching approaches. This improvement can likely be attributed to the increased level of interaction among learners, educators, and educational resources that is characteristic of the 5Es framework. During lessons structured around this model, students are encouraged to engage in activities such as describing phenomena, posing inquiries, formulating explanations, testing these explanations against established scientific principles, and sharing their ideas with classmates. Such interactive learning experiences are instrumental in fostering deeper understanding and retention of knowledge.

This finding affirms the assertion of Boddy, Watson and Aubusson (2003) that using the 5Es Instructional Model in science teaching helps students to better retain concepts in their minds. The finding is also in accord with the research outcomes of Udogu and Njelita (2010), Bunkure (2012) and Ibrahim (2015). These independent studies agree on the efficacy of 5Es Instructional Model in significantly improving the retention scores when compared to those exposed to the Traditional Lecture Method. A study by Chukwuemeka Odumegwu Ojukwu University analyzed the impact of the 5E Learning Cycle Model on senior secondary school students' achievement and retention in geometry. The findings indicated that students taught with the 5E model had higher retention scores compared to those taught using conventional methods, demonstrating

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its effectiveness in enhancing knowledge retention. This study conducted by Chiakyor, Akoja and Nomor (2024) examined the impact of the 5E Learning Model on students with different learning styles in Social Studies. Results showed that students taught using the 5E model had significantly higher retention scores compared to those taught with traditional methods, particularly among reading-writing and kinaesthetic learners, indicating that the 5E model enhances long-term retention of knowledge.

A comparative meta-analysis by Anil and Batdi (2017) evaluated the effects of the 5E instructional model versus traditional teaching methods on students' academic achievement and retention. The findings showed that the 5E model not only improved immediate learning outcomes but also significantly enhanced students' ability to retain knowledge over time, supporting its use as an effective teaching strategy.

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CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Overview

This chapter presents the summary of the whole work and the conclusion drawn from the work. Also presented are recommendations made from the study and suggestions for further research.

5.1 Summary

The research was conducted to evaluate the effectiveness of the 5Es Instructional Model compared to conventional teaching methods in enhancing student performance and retention in photosynthesis among secondary school biology students in Akroso Senior High Technical School in the Asene Manso Akroso district. The study aimed to determine whether this model, which emphasizes engagement, exploration, explanation, elaboration, and evaluation, could lead to better learning outcomes. A quasi-experimental design was employed, involving pre-tests and post-tests with control and experimental groups to assess the impact of the instructional methods. Before treatment, a pre-test was given to ensure group homogeneity and to assess the students' initial level of science process-skill acquisition and academic achievement in photosynthesis. The experimental group was taught using the 5Es Instructional Package (5-EIP), which was based on a model developed from Bybee et al. (2006), whereas the control group was instructed using the Conventional Method. The treatment lasted four weeks. Four sessions were presented on the topic of photosynthesis, which was adapted from the GES Senior Secondary Biology Curriculum (2010). A post-test was given immediately following the treatment to assess students' process-skills acquisition and academic performance in the topic taught. Two weeks after the post-test, both groups

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were given a post-posttest to assess their capacity to retain the learned knowledge. The data was collected using two (2) instruments: the Science Process Skills Acquisition Test (SPSAT) and the Photosynthesis Performance Test (PhPT).

The gathered data were subjected to descriptive statistics of the Independent Samples t-test to test the null hypotheses at $p < 0.05$ levels of significance, as well as descriptive statistical methods to detect significant differences of Means and Standard Deviations to answer the research questions. The Statistical Package for Social Sciences (SPSS) IBM Version 27.0 was used for all analyses, which compared the performance of students who were taught using the 5Es model to those who were taught using conventional techniques. The findings from the study revealed that students taught using the 5Es Instructional Model demonstrated significantly higher performance and retention in biology compared to those taught through conventional methods. The data indicated that the 5Es model not only improved students' understanding and retention of the biological concept but also actively engaged them in the learning process, leading to a deeper comprehension. Furthermore, the study highlighted that the interactive nature of the 5Es approach was particularly effective in bridging the gap between theoretical knowledge and practical application, thereby fostering a more conducive learning environment. Differences in performance between male and female students were also observed, suggesting that the 5Es model might influence genders differently, although both groups benefited from the approach.

The study also uncovered notable differences in the effectiveness of the 5Es Instructional Model between male and female students. While both genders showed improved performance and retention when taught using the 5Es model compared to traditional methods, the extent of improvement varied. These findings suggest that the

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5Es model might cater differently to the learning styles of male and female students. This raises important considerations for educators to tailor their teaching strategies further, potentially integrating additional supportive measures to ensure that both genders can maximize their learning outcomes under the 5Es framework. Understanding these gender-specific responses can help refine instructional approaches to achieve more balanced educational benefits.

5.2 Summary of Findings

The key findings from the study are summarized as follows:

The study found a significant difference in the mean science process-skills acquisition scores between students taught using the 5Es Instructional Model and those taught using conventional methods. The experimental group showed a higher mean score, indicating that the 5Es Model was more effective in enhancing science process skills.

There was a significant difference in the mean science process-skills acquisition scores between male and female students taught using the 5Es Instructional Model, with male students outperforming female students. This suggests that while the model was effective overall, it may have had a slightly more pronounced effect on male students.

The study revealed that students taught photosynthesis using the 5Es Instructional Model had significantly higher academic performance scores compared to those taught using conventional methods. This underscores the effectiveness of the 5Es Model in improving students' understanding and application of biological concepts.

The study found no significant difference in the academic performance scores between male and female students taught using the 5Es Instructional Model. This suggests that the model was equally effective for both genders in terms of academic achievement.

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The retention scores of students taught using the 5Es Instructional Model were significantly higher than those of students taught using conventional methods. This indicates that the 5Es Model not only enhances immediate academic performance but also aids in long-term retention of knowledge.

The study also found a significant difference in the retention of science process-skills acquisition scores, with the experimental group retaining these skills more effectively than the control group.

5.3 Conclusion

Based on the findings of the study, the following conclusions were drawn:

The 5Es Instructional Model is more effective than conventional teaching methods in enhancing secondary school Biology students' science process skills, academic performance, and retention of knowledge.

Although the 5Es Model was generally effective for both male and female students, there was a slight gender difference in science process-skills acquisition, with male students benefiting more.

The model was equally effective for male and female students in terms of academic performance, suggesting that it can be implemented broadly without gender bias.

The significant improvement in retention scores suggests that the 5Es Model not only helps students learn more effectively but also helps them retain that knowledge for longer periods.

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5.4 Recommendation

Based on the conclusions, the following recommendations are made:

Teachers should consider adopting the 5Es Instructional Model in teaching complex biological concepts like photosynthesis to enhance students' understanding, skills acquisition, and retention.

Professional development programs should be organized for teachers to familiarize them with the 5Es Model and its implementation in the classroom.

The 5Es Instructional Model should be integrated into the biology curriculum at the secondary school level, given its proven effectiveness in improving students' learning outcomes.

Educational policymakers should consider the 5Es Model as a standard instructional approach in science education to foster better academic performance and skill acquisition.

The 5Es Instructional Model should be incorporated into teacher-training programs at universities and colleges of education. This will introduce aspiring biology teachers to the field's potential, give them the necessary tools, and inspire them to use this approach when they are in the field.

Research should be carried out to explore the factors that contribute to the gender differences seen in the acquisition of science process skills when using the 5Es Model. Future research should investigate the effects of the 5Es Instructional Model on various science subjects and at different educational levels to assess its overall effectiveness.

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5.5 Suggestions for Further Studies

The following suggestions are put forward for further studies:

1. Similar study could be conducted in other Metropolitan, Municipal and Districts in the country.
2. Studies of this kind could be extended to other educational levels such as primary schools, junior secondary schools and higher institutions of learning like colleges of education and universities.
3. The 5Es Instructional Model can be compared against other teaching strategies such as Guided- Inquiry, role playing, Laboratory-Based Approach and Project Method among others, to determine its relative efficacy.
4. Studies could also be done on the challenges teachers face when implementing the 5Es model and how professional development can enhance its effectiveness.

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APPENDICES

APPENDIX A

List of Abbreviation

BECE	Basic Education Certificate Examination
BSCS	Biological Sciences Curriculum Study
CLT	Constructivism Learning Theory
LCM	Learning Cycle Model
PhPT	Photosynthesis Performance Test
SHS	Senior High School
SHTS	Senior Technical Technical School
SPSAT	Science Process Skills Acquisition Test
UEW	University Education, Winneba
WAEC	West Africa Examination Council
WASSCE	West African Senior School Certificate Examination

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APPENDIX B

PRE-TEST QUESTION

PHOTOSYNTHESIS PERFORMANCE TEST

Student number_____ Duration: 1 hour

Gender of Student _____

Attempt all questions. Circle only the option which corresponds to chosen answer.

1. The first stable products of photosynthesis is?

a) sucrose b) glucose

c) fructose d) starch

2. The main site of photosynthesis in green leaves is the

a) stomata b) spongy mesophyll

c) guard cell d) palisade mesophyll

3. What is the name of the green pigment found in plants that absorbs sunlight for photosynthesis?

a) Chloroplast b) Chlorophyll

c) Cytochrome d) Carotenoid

4. Where does the light-dependent stage of photosynthesis take place?

a) Mitochondria b) Chloroplasts

c) Cytoplasm d) Cell wall

5. What is the overall equation for photosynthesis?

a) $6CO_2 + 6H_2O \rightarrow C6H_{12}O_6 + 6O_2$

b) $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO2 + 6H_2O$

c) $6CO_2 + 6O_2 \rightarrow C_6H_{12}O_6 + 6H_2O$

d) $6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

6. Which of the following is a reactant in photosynthesis?

a) Oxygen b) Glucose

c) Carbon dioxide d) Chlorophyll

7. Which of the following is a product of photosynthesis?

a) Water b) Carbon dioxide

c) Oxygen d) Chlorophyll

8. What is the name of the process that captures light energy during photosynthesis?

a) Light-dependent reactions

b) Light-independent reactions

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c) Calvin cycle

d) Electron transport chain

9. What is the name of the process that converts carbon dioxide into glucose during photosynthesis?

a) Light-dependent reactions

b) Light-independent reactions

c) Calvin cycle

d) Electron transport chain

10. Which of the following is required for photosynthesis to occur?

a) Sunlight b) Carbon dioxide

c) Water d) All of the above

11. What is the primary role of photosynthesis in the ecosystem?

a) Producing food for heterotrophs

b) Recycling carbon dioxide and releasing oxygen

c) Converting light energy into chemical energy

d) All of the above

12. What is the primary function of chlorophyll in photosynthesis?

a) To absorb carbon dioxide

b) To produce glucose

c) To capture light energy

d) To release oxygen

13 How does the process of photosynthesis contribute to the overall balance of gases in the atmosphere?

a) By increasing the concentration of oxygen

b) By decreasing the concentration of carbon dioxide

c) By increasing the concentration of water vapor

d) By decreasing the concentration of nitrogen

14. If a plant is placed in an environment with reduced carbon dioxide levels, how would this affect its rate of photosynthesis?

a) The rate of photosynthesis would increase.

b) The rate of photosynthesis would remain the same.

c) The rate of photosynthesis would decrease.

d) The plant would stop photosynthesizing altogether.

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15. Which stage of photosynthesis involves the conversion of light energy into chemical energy?

a) Calvin cycle

b) Electron transport chain

c) Carbon fixation

d) Light-dependent reactions

16. Why are plants considered autotrophs?

a) Because they produce their own food through photosynthesis

b) Because they consume other organisms for energy

c) Because they rely on fungi for nutrients

d) Because they do not require sunlight for growth

17. How might a decrease in temperature affect the rate of photosynthesis in a plant?

a) It would increase the rate of photosynthesis.

b) It would have no effect on the rate of photosynthesis.

c) It would decrease the rate of photosynthesis.

d) It would cause the plant to switch to cellular respiration.

18. If a researcher measures an increase in oxygen production during a photosynthesis experiment, what can be inferred about the rate of photosynthesis?

a) The rate of photosynthesis is decreasing.

b) The rate of photosynthesis is increasing.

c) The rate of photosynthesis is remaining constant.

d) The rate of photosynthesis cannot be determined from this information.

19. How might the removal of chlorophyll from a plant affect its ability to photosynthesize?

a) It would have no effect on photosynthesis.

b) It would increase the rate of photosynthesis.

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c) It would decrease the rate of photosynthesis.

d) It would prevent the plant from producing glucose.

20. Which organelle within plant cells is primarily responsible for conducting photosynthesis?

a) Nucleus b) Mitochondria

c) Chloroplast d) Golgi apparatus

21. How does the process of photosynthesis contribute to the global carbon cycle?

a) By releasing carbon dioxide into the atmosphere

b) By removing carbon dioxide from the atmosphere

c) By converting carbon dioxide into glucose

d) By breaking down glucose to release carbon dioxide

22. Which of the following statements best compares the light-dependent and light-independent reactions of photosynthesis?

a) The light-dependent reactions produce ATP and NADPH, while the light-independent reactions use these molecules to fix carbon dioxide.

b) The light-independent reactions occur in the thylakoid membrane, while the light-dependent reactions occur in the stroma.

c) The light-dependent reactions require carbon dioxide, while the light-independent reactions require light energy.

d) The light-independent reactions produce oxygen gas, while the light-dependent reactions produce glucose.

23. What effect would a decrease in the concentration of chlorophyll molecules have on the rate of photosynthesis?

a) The rate of photosynthesis would increase.

b) The rate of photosynthesis would remain constant.

c) The rate of photosynthesis would decrease.

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d) The rate of photosynthesis would become unpredictable.

24. If the concentration of carbon dioxide in the environment is doubled, what impact would this likely have on the rate of photosynthesis?

a) It would increase linearly.

b) It would decrease linearly.

c) It would increase exponentially.

d) It would have no effect on the rate of photosynthesis.

25. Which of the following sequences accurately represents the flow of electrons during the light-dependent reactions of photosynthesis?

a) Photosystem II → Electron transport chain → Photosystem I

b) Photosystem I → Electron transport chain → Photosystem II

c) Electron transport chain → Photosystem I → Photosystem II

d) Electron transport chain → Photosystem II → Photosystem I

26. 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) Water b) Sunlight

c) Chlorophyll d) Carbon dioxide

27. Which of the following is not a way in which the glucose manufactured during photosynthesis is used by plants?

a) As a source of energy for their activities.

b) For building up many organic molecules the plant needs.

c) Converted to sucrose, starch and oils for storage.

d) Used to enrich the soil as organic fertilizer.

28. Photosynthesis is considered beneficial to the environment because

a) It encourages the breeding of mosquitoes as the environment gets bushy.

b) It adds to soil fertility by nitrogen fixation.

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c) It purifies the atmosphere by adding Oxygen and removing Carbon dioxide.

d) It encourages bush burning when the plants dry out.

29. Photosynthesis is considered the only means of sustaining life on earth because

a) Only through photosynthesis can the sun's enormous energy be tapped and converted to food for plants and animals on earth.

b) Only through photosynthesis can water be split into Hydrogen and Hydroxide ions.

c) Only through photosynthesis can Carbon dioxide be removed and Oxygen be supplied to the atmosphere.

d) Only through photosynthesis can plants grow to beautify the environment for man.

30. If you were tasked with designing an educational poster to explain the process of photosynthesis to younger students, which of the following elements would you include to ensure clarity and engagement?

a) Complex scientific diagrams and equations

b) Bright and colourful illustrations showing the steps of photosynthesis

c) Lengthy paragraphs of text detailing biochemical reactions

d) Technical vocabulary without simplification

31. Which is correct regarding photosynthesis?

a) Carbon dioxide is obtained from the atmosphere

b) Water is absorbed from the soil through the stem system

c) Sunlight is trapped by pigments called xanthophyll

d) Chlorophyll absorbs green light

32. The half leaf experiment showed that _____ is important for photosynthesis.

a) O_2 b) CO_2

c) Sunlight d) Chlorophyll

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33. A compound was used in the half leaf experiment to absorb CO2. This compound is

a) KMNO4 b) HCl

c) NaOH d) KOH

34. Sweet potato is an underground structure which stores food. Where is the food prepared in this plant?

a) Leaves b) Fruit

c) Stem d) Root

35. Where does the light reaction take place?

a) Grana b) Stroma

c) Cytoplasm d) Endoplasmic reticulum

36. Non-cyclic photophosphorylation results in the production of

a) NADH b) NADPH

c) ATP d) ATP and NADPH

37. Maximum photosynthesis occurs in

a) Blue light b) Red light

c) White light d) Green light

38. Starch is then stored in stems or roots of the plants and can be broken down to _____ whenever it is needed.

a) ATP b) Glucose

c) NADPH d) None of the above

39. Each cluster of pigments is known as a

a) Protein b) Stomata

c) Photosystem d) None of the above

40. Farmers will use heated greenhouses for faster growth of crops. This increases photosynthesis by increasing the...

a) pH b) light intensity

c) temperature d) water

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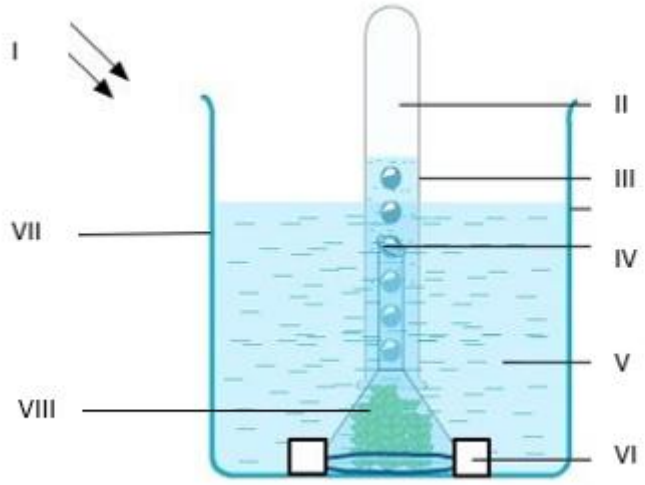
APPENDIX C

PRE-TEST QUESTION

SCIENCE PROCESS-SKILLS ACQUISITION TEST (SPSAT)

Students ID_____ Duration:

1hr:30min



The diagram above illustrates an experimental set-up demonstrating a biological process in plants. Study it carefully and answer the (a) to (d).

1) Identify the parts labelled **I** to **VIII**

_____

_____

_____

_____

_____

[8 marks]

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2) What is the aim of the experiment?

_____

_____

_____

[1 mark]

3) Name two factors that can affect the results of the experiment?

_____

_____

[2 marks]

4) What type of liquid is used in the part labelled **V**

_____

[1 mark]

5) Name one organism that can be used in the part labelled **VIII**

_____

[1 mark]

6) What process produced the substance labelled **IV**

_____

[1 mark]

7) Explain the test that confirm the nature of the substance labelled **II**

_____

_____

_____

[2 marks]

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8) Suggest a suitable control for the experiment

_____

_____

[1 mark]

9) Write a balanced chemical equation of the biological process involved in the experiment.

_____

_____

[2 mark]

Study the table below and answer the questions that follows

Light intensity	5	10	15	20	25	30	35	40	45	50
Rate of photosynthesis	10	40	50	60	70	75	75	75	75	75

10. Using a scale of 1cm to 10units on the y-axis and 1cm to 5 units on the x-axis, plot a graph showing the rate of photosynthesis on the y-axis and light intensity on x-axis.

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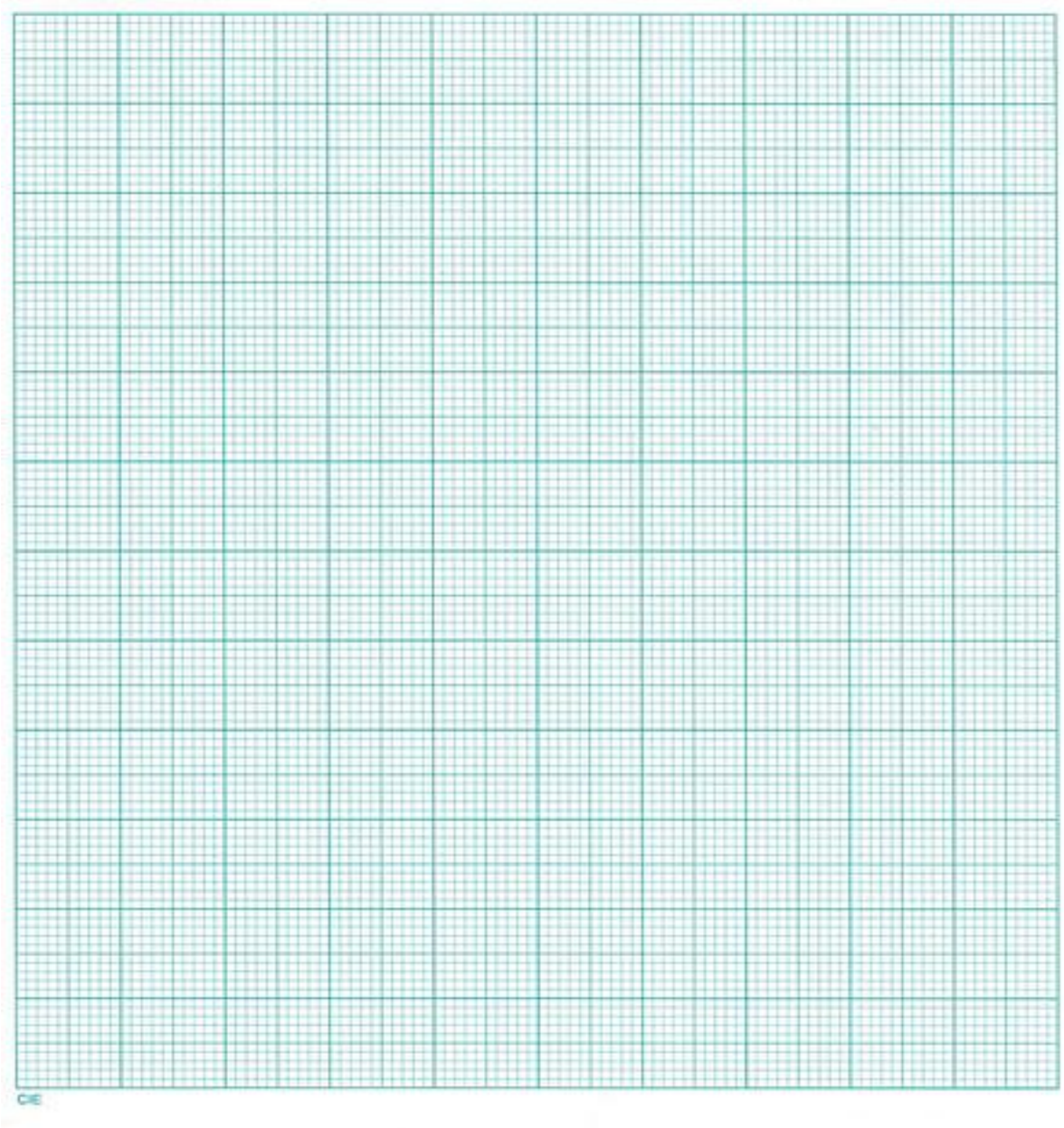

[8 marks]

11. From the plotted graph in (10), explain briefly the effect of light intensity on the rate of photosynthesis

_____

_____

_____

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_____

_____

_____

[3 marks]

12. List three other factors that affect the rate of photosynthesis.

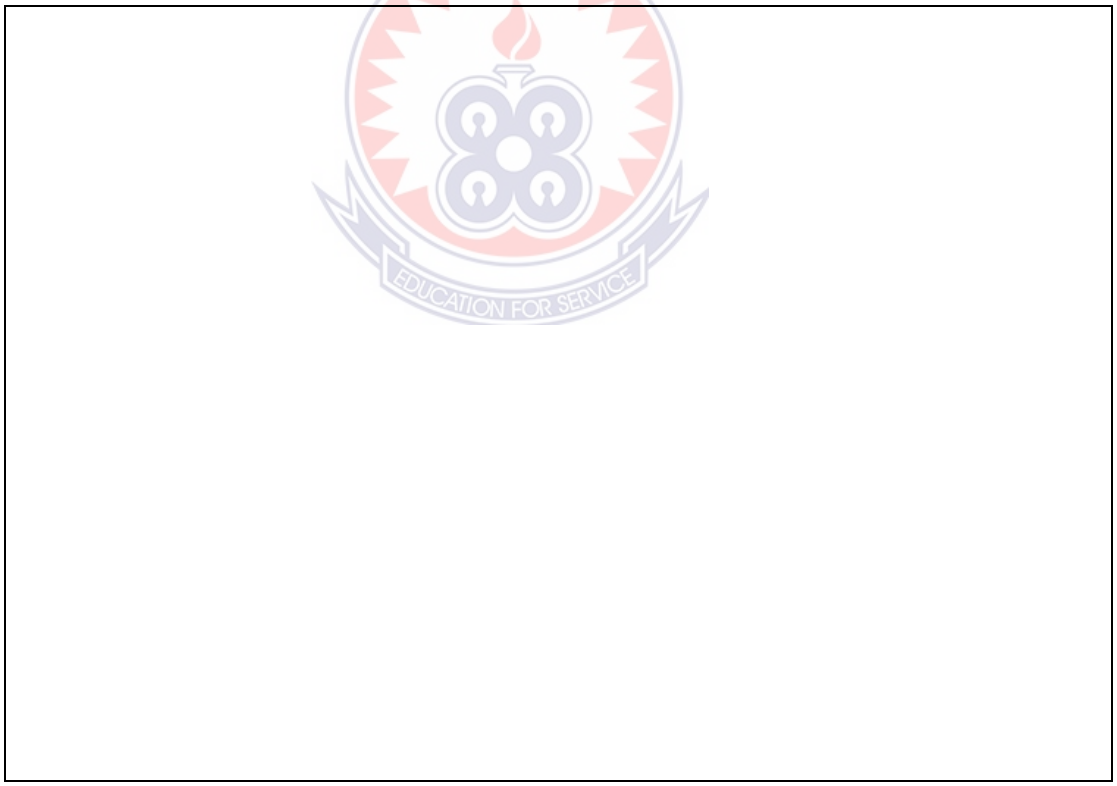
_____

_____

_____

[3 marks]

13. Make a drawing 8cm to 10cm of the chloroplast and label fully.



[6 marks]

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14. Describe the role of chloroplasts in plant cells and explain why they are essential for photosynthesis.

_____

_____

_____

_____

_____

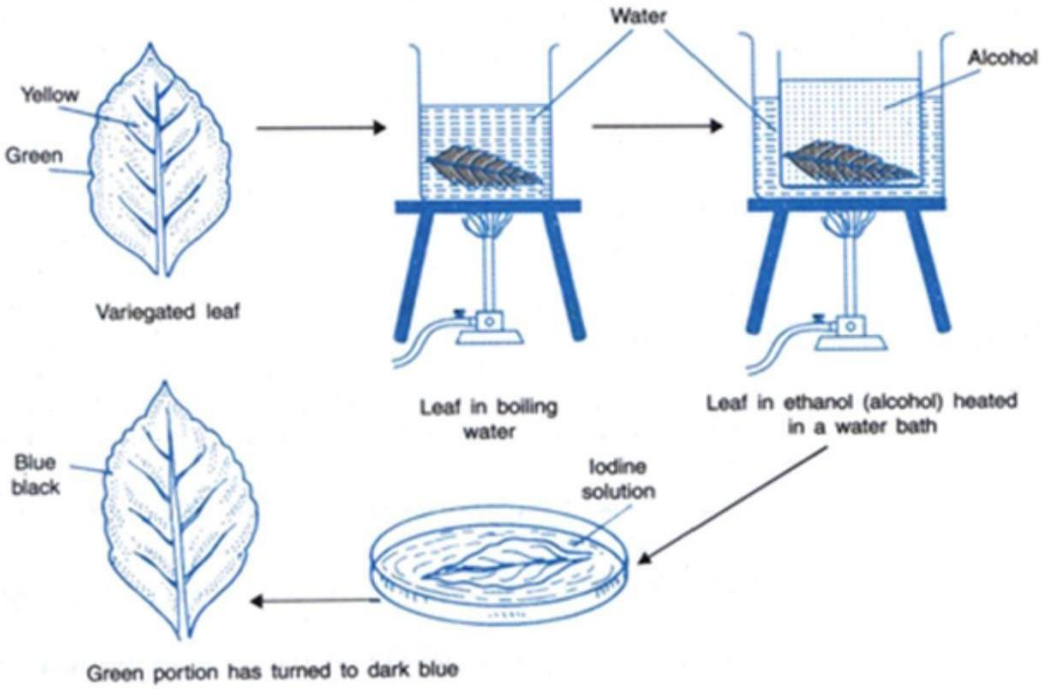
_____

_____

_____

[4 marks]

The diagram below illustrates an experimental set-up demonstrating test for starch in leaf. Study it carefully and answer the (15) to (25).



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15. What is the purpose of placing the fresh leaves in boiling water before testing for starch?

_____

_____

[1 mark]

16. Predict what would happen if the leaves were not placed in cold ethanol after boiling. How would this affect the results of the starch test?

_____

_____

_____

[2 marks]

17. Why is it important to rinse the leaves with water after removing them from the ethanol?

_____

[1 mark]

18. If a leaf turns blue-black after adding iodine solution, what can you infer about the presence of starch in that leaf?

_____

_____

[1 mark]

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19. Describe the appearance of a leaf before and after it has been treated with iodine solution. What differences do you observe?

_____

_____

_____

_____

[2 marks]

20. If you were to perform the starch test on a leaf kept in complete darkness for 24 hours, what do you predict the result would be? Explain your reasoning.

_____

_____

_____

_____

_____

[4 marks]

21. Why do we use a white tile or paper when conducting the starch test? How does this aid in observation?

_____

_____

_____

[2 marks]

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22. If a leaf does not change color after adding iodine solution, what inference can you make about the presence of starch in that leaf?

_____

_____

_____

[1 mark]

23. What would happen if iodine solution is added to a leaf that has been exposed to strong sunlight for several hours? Predict the possible outcome and explain your reasoning.

_____

_____

_____

[1 mark]

24. During the experiment, what changes did you observe in the iodine solution after it was added to the leaf? How do these changes relate to the presence or absence of starch?

_____

_____

_____

[2 marks]

25. How would you classify a leaf that exhibits a faint color change after the starch test? What might this indicate about the amount of starch present in the leaf?

_____

_____

[2 marks]

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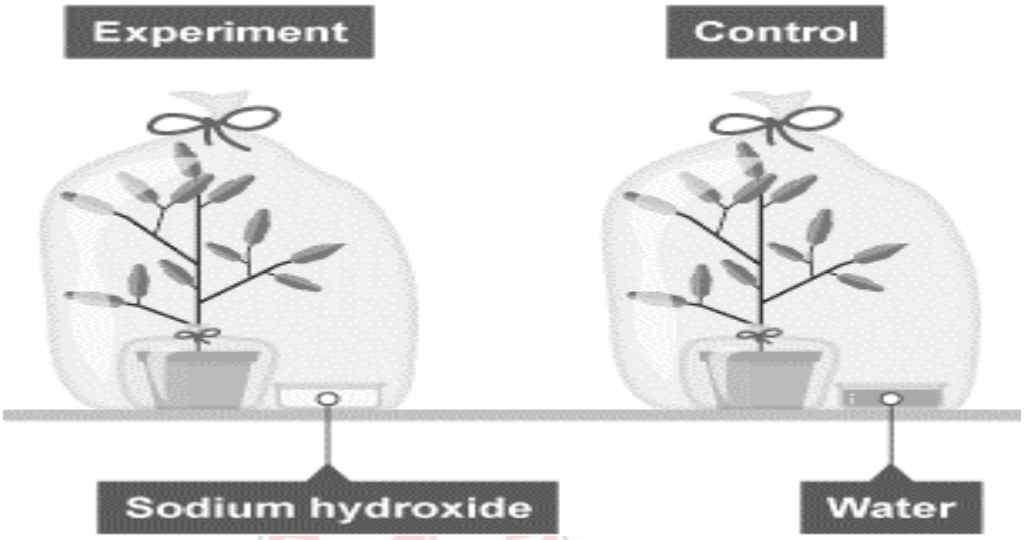
A student put together two different experimental setups as shown below. Answer the questions below that relate to this experiment.



26. What factor is the student varying?

_____

_____

[1 mark]

27. Assume that the students plant '**A**' in indirect sunlight for two days. After this time, the students tested one leaf from the plant for starch content. What would you expect the results to be?

_____

_____

_____

_____

[2 marks]

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28. Classify the role of the factor in photosynthesis as "essential," "beneficial but not essential," or "not necessary." Justify your classification with evidence from the experiment.

_____

_____

_____

_____

_____

[2 marks]

29. What is the role of the sodium hydroxide in the experiment.

_____

_____

[1 mark]

30. Make a prediction about the effect of carbon dioxide on starch production in plants.

_____

_____

_____

[2 marks]

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APPENDIX D

POST TEST QUESTION

PHOTOSYNTHESIS PERFORMANCE TEST

Student number_____ Duration: 1 hour

Gender of Student _____

Answer all questions. Circle the right answer form the options provided.

1. What are the primary products of photosynthesis?

a) Oxygen and water

b) Glucose and oxygen

c) Carbon dioxide and water

d) Glucose and carbon dioxide

2. Which layer of a leaf contains cells with the highest number of chloroplasts for photosynthesis?

a) Epidermis

b) Spongy mesophyll

c) Palisade mesophyll

d) Guard cells

3. During photosynthesis, light energy is captured by what type of pigment in plants?

a) Carotenoids

b) Xanthophylls

c) Chlorophyll

d) Flavonoids

4. The light-dependent reactions occur in the _____ of the chloroplast.

a) Thylakoid membranes

b) Stroma

c) Cytoplasm

d) Outer membrane

5. Complete the chemical equation for photosynthesis:

$6CO_2 + 6H_2O \rightarrow$ _____ $+ 6O_2$.

a) $C_6H_{10}O_6$ b) $C_6H_{12}O_6$

c) $C_5H_{10}O_5$ d) $C_6H_8O_6$

6. Which molecule is a reactant in the photosynthesis process?

a) Oxygen b) Carbon dioxide

c) Glucose d) Water vapor

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7. Explain why the Calvin Cycle is important to photosynthesis.

a) It absorbs light to generate ATP.

b) It converts carbon dioxide into glucose.

c) It releases oxygen into the atmosphere.

d) It breaks down glucose for energy.

8. What happens to the rate of photosynthesis if a plant receives light only in the green spectrum?

a) It increases significantly.

b) It remains unchanged.

c) It decreases significantly.

d) It stops completely.

9. Describe the role of water in photosynthesis.

a) Provides oxygen to the plant's roots.

b) Supplies electrons and protons in the light-dependent reactions.

c) Acts as a carrier molecule in the Calvin Cycle.

d) Acts as a storage medium for glucose.

10. Why do heated greenhouses improve crop growth?

a) Increased oxygen levels

b) Improved nutrient absorption

c) Higher rates of photosynthesis due to better temperature regulation

d) Reduced competition for sunlight

11. What is the significance of photosynthesis in maintaining atmospheric gas balance?

a) It increases atmospheric carbon dioxide.

b) It releases oxygen and removes carbon dioxide.

c) It releases nitrogen and absorbs oxygen.

d) It increases water vapor in the air.

12. In what way does temperature affect the rate of photosynthesis?

a) Higher temperatures always speed up photosynthesis.

b) Lower temperatures have no effect on photosynthesis.

c) Extremely high or low temperatures can reduce photosynthesis rates.

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d) Photosynthesis stops entirely at low temperatures.

13. Which of the following accurately describes the Calvin Cycle?

a) It produces glucose from carbon dioxide using ATP and NADPH.

b) It converts light energy into chemical energy.

c) It breaks down glucose to release energy.

d) It occurs only in the presence of sunlight.

14. What is the role of chlorophyll in photosynthesis?

a) It converts carbon dioxide to oxygen.

b) It traps light energy from the sun.

c) It provides nutrients to the plant.

d) It absorbs water from the soil.

15. If the amount of carbon dioxide in the air is doubled, what would likely happen to the rate of photosynthesis?

a) It would stop entirely.

b) It would decrease.

c) It would increase, but only up to a certain point.

d) It would have no impact on the process.

16. Non-cyclic photophosphorylation results in the production of which substances?

a) ATP and NADPH

b) NADPH and water

c) Oxygen and glucose

d) Carbon dioxide and ATP

17. How does photosynthesis benefit heterotrophs (organisms that cannot produce their own food)?

a) It provides oxygen and removes harmful nitrogen.

b) It produces glucose, which serves as food.

c) It increases soil nutrients for plants.

d) It traps sunlight for energy storage.

18. What happens during the light-dependent reactions of photosynthesis?

a) Glucose is synthesized from carbon dioxide.

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b) Light energy is used to produce ATP and split water molecules.

c) Carbon dioxide is captured and stored as starch.

d) Oxygen is released directly from the Calvin Cycle.

19. A plant is exposed to red light and green light in an experiment. Which light is likely to produce a higher rate of photosynthesis?

a) Green light, because it is reflected by chlorophyll.

b) Red light, because it is absorbed efficiently by chlorophyll.

c) Both produce equal rates, as plants use all light equally.

d) Neither, as only white light supports photosynthesis.

20. What is the primary organelle involved in photosynthesis?

a) Mitochondria b) Nucleus

c) Chloroplast d) Ribosome

21. Farmers often use artificial lights for growing plants indoors. Which type of light is most effective for photosynthesis?

a) Green light b) Blue and red light

c) Yellow light d) Infrared light

22. Why is water essential for the light-dependent reactions in photosynthesis?

a) It absorbs sunlight directly.

b) It supplies electrons and protons when split.

c) It serves as a source of glucose.

d) It stores energy as chemical bonds.

23. What does a decrease in chlorophyll concentration in leaves indicate about the rate of photosynthesis?

a) The rate will increase.

b) The rate will decrease.

c) The rate will remain unchanged.

d) The effect depends on light availability.

24. What effect does increase light intensity have on photosynthesis,

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assuming other factors remain constant?

a) It decreases the rate significantly.

b) It has no effect on the process.

c) It increases the rate up to a saturation point.

d) It slows the Calvin Cycle.

25. What process directly converts light energy into chemical energy during photosynthesis?

a) Calvin Cycle

b) Light-dependent reactions

c) Carbon fixation

d) Glucose metabolism

26. How might the removal of chlorophyll from a plant affect its ability to photosynthesize?

a) It would have no effect on photosynthesis.

b) It would increase the rate of photosynthesis.

c) It would decrease the rate of photosynthesis.

d) It would prevent the plant from producing glucose.

27. Which organelle within plant cells is primarily responsible for conducting photosynthesis?

a) Nucleus b) Mitochondria

c) Chloroplast d) Golgi apparatus

28. How does the process of photosynthesis contribute to the global carbon cycle?

a) By releasing carbon dioxide into the atmosphere

b) By removing carbon dioxide from the atmosphere

c) By converting carbon dioxide into glucose

d) By breaking down glucose to release carbon dioxide

29. Which of the following statements best compares the light-dependent and light-independent reactions of photosynthesis?

a) The light-dependent reactions produce ATP and NADPH, while the light-independent reactions use these molecules to fix carbon dioxide.

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b) The light-independent reactions occur in the thylakoid membrane, while the light-dependent reactions occur in the stroma.

c) The light-dependent reactions require carbon dioxide, while the light-independent reactions require light energy.

d) The light-independent reactions produce oxygen gas, while the light-dependent reactions produce glucose.

30. What effect would a decrease in the concentration of chlorophyll molecules have on the rate of photosynthesis?

a) The rate of photosynthesis would increase.

b) The rate of photosynthesis would remain constant.

c) The rate of photosynthesis would decrease.

d) The rate of photosynthesis would become unpredictable.

31. If the concentration of carbon dioxide in the environment is doubled, what impact would this likely have on the rate of photosynthesis?

a) It would increase linearly.

b) It would decrease linearly.

c) It would increase exponentially.

d) It would have no effect on the rate of photosynthesis.

32. Why is photosynthesis often considered the foundation of most food chains?

a) It provides carbon dioxide for plant respiration.

b) It creates glucose, which is the primary energy source for plants and animals.

c) It directly supplies nutrients to soil bacteria.

d) It produces oxygen, which heterotrophs need to breathe.

33. 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?

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a) Water b) Sunlight

c) Chlorophyll d) Carbon dioxide

34. Which of the following is not a way in which the glucose manufactured during photosynthesis is used by plants?

a) As a source of energy for their activities.

b) For building up many organic molecules the plant needs.

c) Converted to sucrose, starch and oils for storage.

d) Used to enrich the soil as organic fertilizer.

35. Photosynthesis is considered beneficial to the environment because

a) It encourages the breeding of mosquitoes as the environment gets bushy.

b) It adds to soil fertility by nitrogen fixation.

c) It purifies the atmosphere by adding Oxygen and removing Carbon dioxide.

d) It encourages bush burning when the plants dry out.

36. Photosynthesis is considered the only means of sustaining life on earth because

a) Only through photosynthesis can the sun's enormous energy be tapped and converted to food for plants and animals on earth.

b) Only through photosynthesis can water be split into Hydrogen and Hydroxide ions.

c) Only through photosynthesis can Carbon dioxide be removed and Oxygen be supplied to the atmosphere.

d) Only through photosynthesis can plants grow to beautify the environment for man.

37. Which experimental setup can demonstrate the necessity of chlorophyll in photosynthesis?

a) Covering a portion of a leaf to block light exposure

b) Using a variegated leaf and testing for starch after sunlight exposure

c) Growing plants in an environment without carbon dioxide

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d) Measuring oxygen production under different temperatures

38. In the 'half-leaf' experiment, what substance is used to absorb carbon dioxide?

a) Sodium hydroxide (NaOH)

b) Potassium hydroxide (KOH)

c) Hydrochloric acid (HCl)

d) Potassium permanganate ($KMnO_4$)

39. Where does the Calvin Cycle occur within the chloroplast?

a) Thylakoid membranes b) Stroma

c) Grana d) Cytoplasm

40. What type of energy conversion occurs during the light-dependent reactions of photosynthesis?

a) Chemical energy to thermal energy

b) Solar energy to chemical energy

c) Kinetic energy to potential energy

d) Chemical energy to electrical energy

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APPENDIX E

POST-TEST QUESTION

SCIENCE PROCESS-SKILLS ACQUISITION TEST (SPSAT)

Students ID_____ **Duration: 1hr:30min**

Section A (19 marks)

Answer all questions in the spaces provided after each question

The materials in the box below constitute a biological process that is essential to life. Study them and answers that follows.

Oxygen	Glucose
Sunlight	Chlorophyll
Carbon (IV) oxide	Water

1) Use the materials to form equation for the biological process

_____

_____

[1 mark]

2) How many molecules each of the following material are required to balance the equation in question 1

   a) Oxygen _____

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b) Carbon (IV) oxide _____

c) Glucose _____

d) Water _____

[4 marks]

3) Which group of organisms carry out the biological process in **question 1**

_____

_____

[2 marks]

4) In which part of the group of organisms stated in **question 3** does the process occur?

_____

_____

[2 marks]

5) State the three reasons why living things rely solely on the biological process.

_____

_____

_____

_____

[3 marks]

6) State one function each of the following materials in the biological process

a) Sunlight

_____

[1 mark]

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b) Chlorophyll

_____

_____

[1 mark]

7. Make a drawing 8cm to 10cm of the chloroplast and label fully.

[5 marks]

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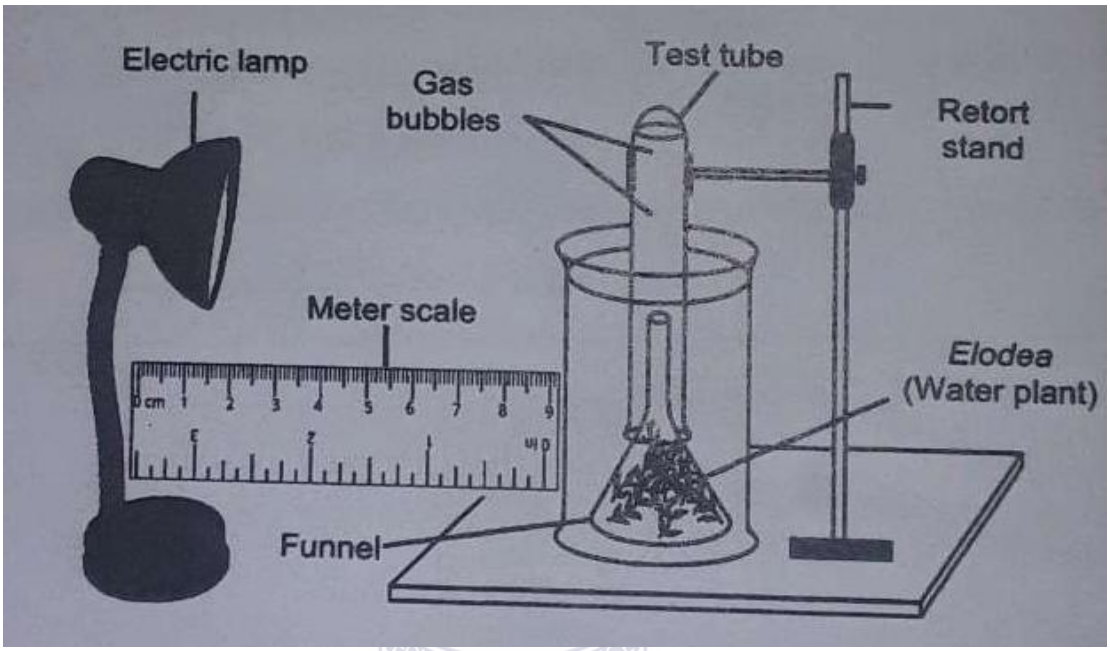
Section B

Experimental Setup and Observation (12 Marks)

An experiment was conducted to study the effect of light intensity on the rate of photosynthesis in a water plant. The plant was submerged in water and placed under a lamp at varying distances. The number of oxygen bubbles released in 1 minute was recorded for each light intensity.



The table below summarizes the results.

Light Intensity	Oxygen Bubbles/Minute
10	5
20	15
30	25
40	35
50	40
60	40
70	40

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8) Describe the purpose of the experiment.

_____

_____

[2 marks]

9) Identify the variable being changed and the variable being measured in this experiment.

_____

[2 marks]

10) Suggest one control variable that must be maintained during the experiment to ensure valid results.

_____

[1 mark]

11) Explain why the rate of photosynthesis stops increasing after a certain light intensity.

_____

_____

_____

_____

[3 marks]

12) Name two other factors, apart from light intensity, that could affect the rate of photosynthesis.

_____

_____

[2 marks]

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13) Write a balanced chemical equation for photosynthesis.

_____

_____

[2 marks]

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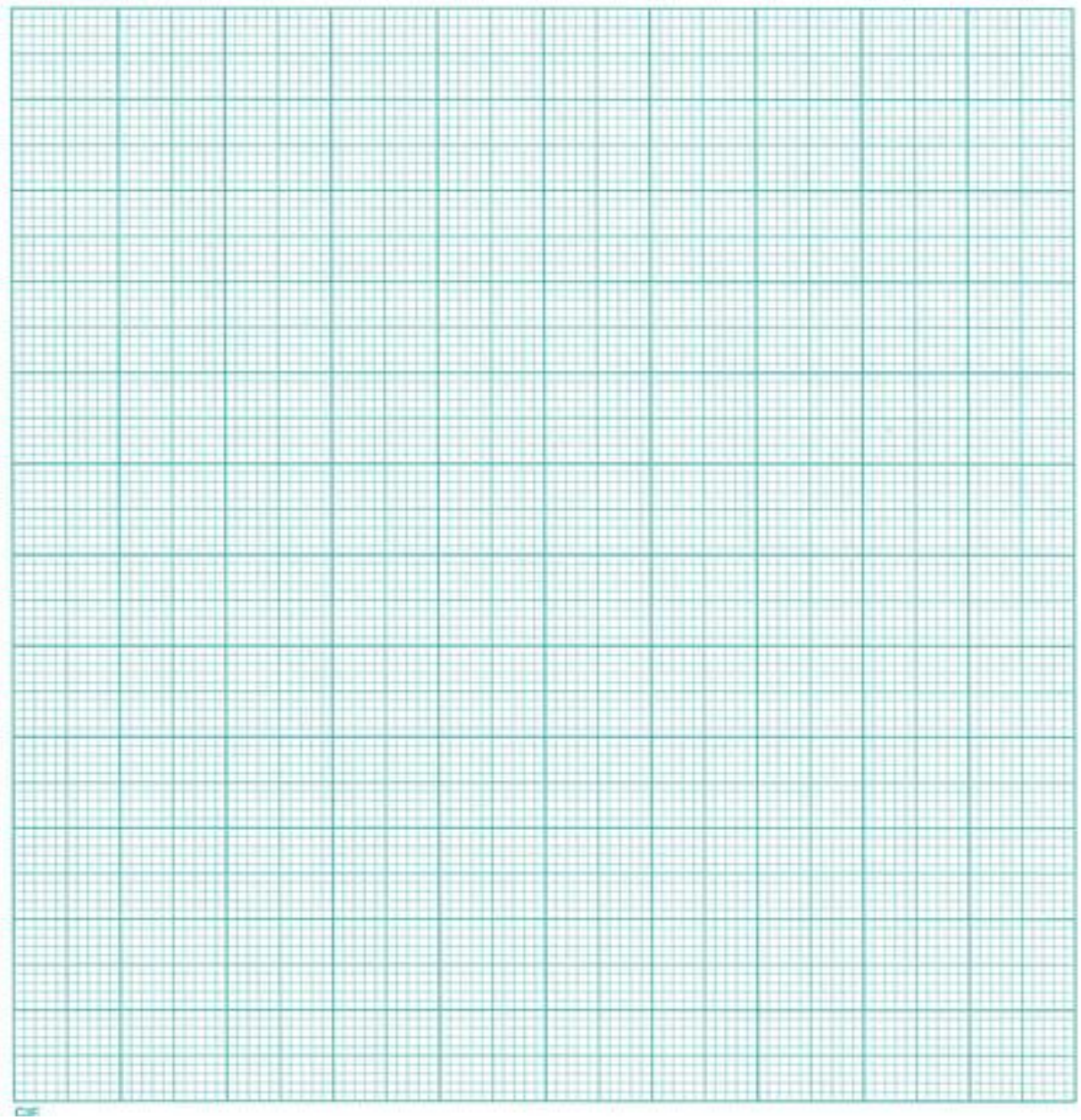
Section C: Graph Plotting and Analysis (31 marks)

Using the data in the table above:

14) Plot a graph of light intensity (x-axis) against oxygen bubbles per minute (y-axis) using a scale of 2cm to 10unit on the x-axis and 2cm to 5unit on the y-axis.



[8 marks]

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15) From your graph, identify:

a) The light intensity at which the rate of photosynthesis reaches a plateau.

_____

_____

[2 marks]

b) The relationship between light intensity and the rate of photosynthesis before the plateau.

_____

_____

_____

[3 marks]

16) Explain why plotting a graph is useful in analyzing experimental data.

_____

_____

_____

[2 marks]

17) If the experiment were conducted with a red-light source instead of white light, how would the rate of photosynthesis change? Justify your answer.

_____

_____

_____

_____

_____

_____

[4 marks]

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18) A student suggested testing the experiment in low-temperature conditions (10°C). Predict how temperature might affect the rate of photosynthesis and the shape of the graph.

[4 marks]

19) Why is it important to use a healthy, green plant for this experiment?

[4 marks]

20) A similar experiment was conducted, but sodium bicarbonate was added to the water to increase carbon dioxide availability. Predict how the graph might differ and explain your reasoning.

[4 marks]

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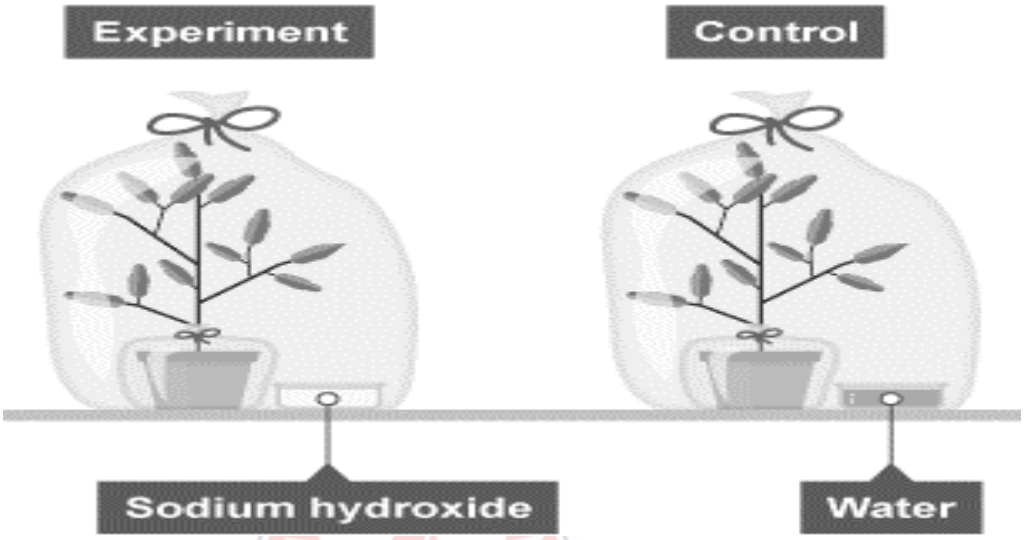
A student put together two different experimental setups as shown below. Answer the questions below that relate to this experiment.



21. What factor is the student varying?

_____

_____

[1 mark]

22. Assume that the students plant '**A**' in indirect sunlight for two days. After this time, the students tested one leaf from the plant for starch content. What would you expect the results to be?

_____

_____

_____

_____

[2 marks]

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23. Classify the role of the factor in photosynthesis as "essential," "beneficial but not essential," or "not necessary." Justify your classification with evidence from the experiment.

_____

_____

_____

_____

_____

[2 marks]

24. What is the role of the sodium hydroxide in the experiment.

_____

_____

[1 mark]

25. Make a prediction about the effect of carbon dioxide on starch production in plants.

_____

_____

_____

[2 marks]

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APPENDIX F

Marking scheme for PhPT (Pre-test)

Here are the correct answers to the questions from the document;

1. The first stable products of photosynthesis is?

d) starch

2. The main site of photosynthesis in green leaves is the

d) palisade mesophyll

3. What is the name of the green pigment found in plants that absorbs sunlight for photosynthesis?

b) Chlorophyll

4. Where does the light-dependent stage of photosynthesis take place?

b) Chloroplasts

5. What is the overall equation for photosynthesis?

a) $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

6. Which of the following is a reactant in photosynthesis?

c) Carbon dioxide

7. Which of the following is a product of photosynthesis?

c) Oxygen

8. What is the name of the process that captures light energy during photosynthesis?

a) Light-dependent reactions

9. What is the name of the process that converts carbon dioxide into glucose during photosynthesis?

c) Calvin cycle

10. Which of the following is required for photosynthesis to occur?

d) All of the above (Sunlight, Carbon dioxide, Water)

11. What is the primary role of photosynthesis in the ecosystem?

d) All of the above (Producing food for heterotrophs, Recycling carbon dioxide and releasing oxygen, Converting light energy into chemical energy)

12. What is the primary function of chlorophyll in photosynthesis?

c) To capture light energy

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13. How does the process of photosynthesis contribute to the overall balance of gases in the atmosphere?

a) By increasing the concentration of oxygen

14. If a plant is placed in an environment with reduced carbon dioxide levels how would this affect its rate of photosynthesis?

c) The rate of photosynthesis would decrease.

15. Which stage of photosynthesis involves the conversion of light energy into chemical energy?

d) Light-dependent reactions

16. Why are plants considered autotrophs?

a) Because they produce their own food through photosynthesis

17. How might a decrease in temperature affect the rate of photosynthesis in a plant?

c) It would decrease the rate of photosynthesis.

18. If a researcher measures an increase in oxygen production during a photosynthesis experiment what can be inferred about the rate of photosynthesis?

b) The rate of photosynthesis is increasing.

19. How might the removal of chlorophyll from a plant affect its ability to photosynthesize?

d) It would prevent the plant from producing glucose.

20. Which organelle within plant cells is primarily responsible for conducting photosynthesis?

c) Chloroplast

21. How does the process of photosynthesis contribute to the global carbon cycle?

b) By removing carbon dioxide from the atmosphere

22. Which of the following statements best compares the light-dependent and light-independent reactions of photosynthesis?

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a) The light-dependent reactions produce ATP and NADPH while the light-independent reactions use these molecules to fix carbon dioxide.

23. What effect would a decrease in the concentration of chlorophyll molecules have on the rate of photosynthesis?

c) The rate of photosynthesis would decrease.

24. If the concentration of carbon dioxide in the environment is doubled what impact would this likely have on the rate of photosynthesis?

a) It would increase linearly.

25. Which of the following sequences accurately represents the flow of electrons during the light-dependent reactions of photosynthesis?

a) Photosystem II → Electron transport chain → Photosystem I

26. 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?

c) Chlorophyll

27. Which of the following is not a way in which the glucose manufactured during photosynthesis is used by plants?

d) Used to enrich the soil as organic fertilizer.

28. Photosynthesis is considered beneficial to the environment because

c) It purifies the atmosphere by adding Oxygen and removing Carbon dioxide.

29. Photosynthesis is considered the only means of sustaining life on earth because

a) Only through photosynthesis can the sun's enormous energy be tapped and converted to food for plants and animals on earth.

30. If you were tasked with designing an educational poster to explain the process of photosynthesis to younger students which of the following elements, would you include to ensure clarity and engagement?

b) Bright and colorful illustrations showing the steps of photosynthesis

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31. Which is correct regarding photosynthesis?

a) Carbon dioxide is obtained from the atmosphere

32. The half leaf experiment showed that _____ is important for photosynthesis.

c) Sunlight

33. A compound was used in the half leaf experiment to absorb CO2. This compound is __

d) KOH

34. Sweet potato is an underground structure which stores food. Where is the food prepared in this plant?

a) Leaves

35. Where does the light reaction takes place?

a) Grana

36. Non-cyclic photophosphorylation results in the production of

d) ATP and NADPH

37. Maximum photosynthesis occurs in

c) White light

38. Starch is then stored in stems or roots of the plants and can be broken down to _____ whenever it is needed.

b) Glucose

39. Each cluster of pigments is known as a

c) Photosystem

40. Farmers will use heated greenhouses for faster growth of crops. This increases photosynthesis by increasing the...

c) temperature

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APPENDIX G

Marking Scheme for PhPT Posttest/Post-Posttest

1. b) Glucose and oxygen
2. c) Palisade mesophyll
3. c) Chlorophyll
4. a) Thylakoid membranes
5. b) $C_6H_{12}O_6$
6. b) Carbon dioxide
7. b) It converts carbon dioxide into glucose.
8. c) It decreases significantly.
9. b) Supplies electrons and protons in the light-dependent reactions.
10. c) Higher rates of photosynthesis due to better temperature regulation.
11. b) It releases oxygen and removes carbon dioxide.
12. c) Extremely high or low temperatures can reduce photosynthesis rates.
13. a) It produces glucose from carbon dioxide using ATP and NADPH.
14. b) It traps light energy from the sun.
15. c) It would increase, but only up to a certain point.
16. a) ATP and NADPH
17. b) It produces glucose, which serves as food.
18. b) Light energy is used to produce ATP and split water molecules.
19. b) Red light, because it is absorbed efficiently by chlorophyll.
20. c) Chloroplast
21. b) Blue and red light
22. b) It supplies electrons and protons when split.
23. b) The rate will decrease.

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24. c) It increases the rate up to a saturation point.

25. b) Light-dependent reactions

26. d) It would prevent the plant from producing glucose.

27. c) Chloroplast

28. b) By removing carbon dioxide from the atmosphere.

29. a) The light-dependent reactions produce ATP and NADPH, while the light-independent reactions use these molecules to fix carbon dioxide.

30. c) The rate of photosynthesis would decrease.

31. c) It would increase exponentially.

32. b) It creates glucose, which is the primary energy source for plants and animals.

33. c) Chlorophyll

34. d) Used to enrich the soil as organic fertilizer.

35. c) It purifies the atmosphere by adding oxygen and removing carbon dioxide.

36. a) Only through photosynthesis can the sun's enormous energy be tapped and converted to food for plants and animals on earth.

37. b) Using a variegated leaf and testing for starch after sunlight exposure.

38. b) Potassium hydroxide (KOH)

39. b) Stroma

40. b) Solar energy to chemical energy

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APPENDIX H

Marking Scheme for SPSAT (Posttest/Post-Posttest)

Section A:

1. **Use the materials to form an equation for the biological process**

   Answer: Carbon(IV)oxide +Water

   [2 marks]

2. **How many molecules each of the following materials are required to balance the equation in question 1?**

   - Oxygen: **6**
   - Carbon (IV) oxide: **6**
   - Glucose: **1**
   - Water: **6**

   [4 marks]

3. **Which group of organisms carry out the biological process in question 1?**

   Answer: Plants, algae, and photosynthetic bacteria.

   [2 marks]

4. **In which part of the group of organisms stated in question 3 does the process occur?**

   Answer: In the chloroplasts of plant and algal cells, and in specialized membranes of photosynthetic bacteria.

   [2 marks]

5. **State the three reasons why living things rely solely on the biological process.**

   Answer:

   - It produces oxygen necessary for respiration.
   - It forms the basis of the food chain by producing glucose.

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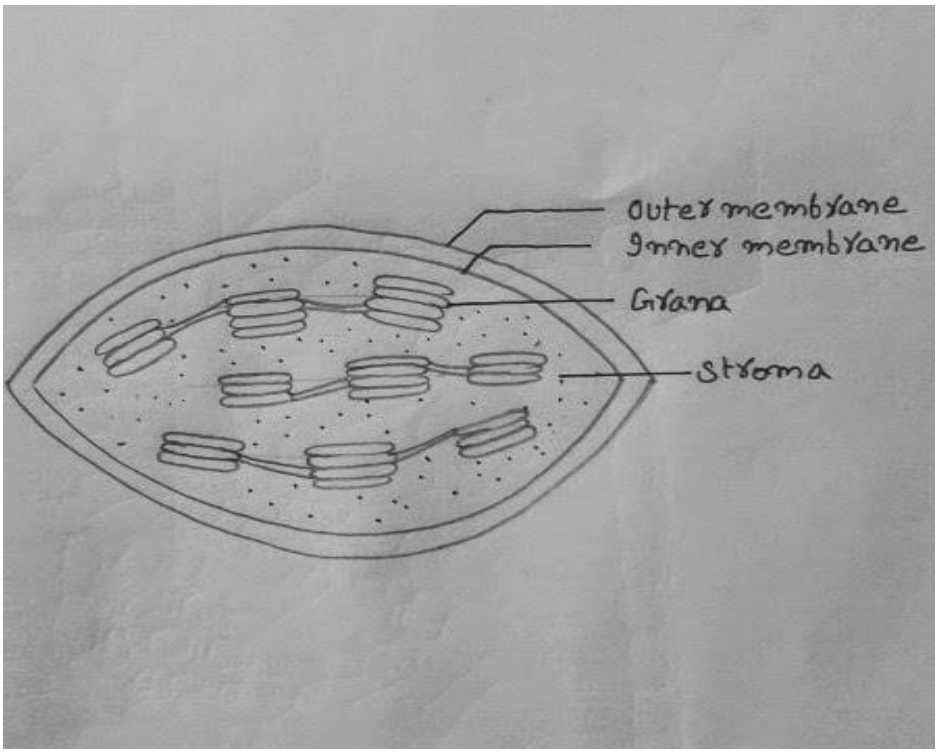
- It helps regulate atmospheric carbon dioxide levels.

[3 marks]

6. **State one function each of the following materials in the biological process:**
   - **Sunlight:** Provides energy for the light-dependent reactions. **[1 mark]**
   - **Chlorophyll:** Captures light energy to drive the photosynthesis process. **[1 mark]**
7. **Make a drawing of the chloroplast and label it fully.**

   Answer:



Section B

8. **Describe the purpose of the experiment.**

   Answer: To study the effect of light intensity on the rate of photosynthesis.

[2 marks]

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9. **Identify the variable being changed and the variable being measured in this experiment.**

    - Variable being changed: **Light intensity**

    Variable being measured: **Rate of photosynthesis (oxygen bubbles per minute)** **[2 marks]**

    -

10. **Suggest one control variable that must be maintained during the experiment to ensure valid results.**

    Answer: The temperature of the water. **[1 mark]**

11. **Explain why the rate of photosynthesis stops increasing after a certain light intensity.**

    Answer: Photosynthesis becomes limited by other factors, such as the saturation of chlorophyll or the availability of carbon dioxide and water.

    [3 marks]

12. **Name two other factors, apart from light intensity, that could affect the rate of photosynthesis.**

    Answer:

    - Carbon dioxide concentration
    - Temperature

    [2 marks]

13. **Write a balanced chemical equation for photosynthesis.**

    Answer:

    [2 marks]

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Section C:

14. **Plot a graph of light intensity against oxygen bubbles per minute.**

    Answer: Plot a line graph with light intensity on the x-axis and oxygen bubbles per minute on the y-axis. Use the given scales (2 cm = 10 units on x, 2 cm = 5 units on y).

15. **From your graph, identify:**

    a) **The light intensity at which the rate of photosynthesis reaches a plateau:**

    Answer: 50–60 units of light intensity. **[1 mark]**

    b) **The relationship between light intensity and the rate of photosynthesis before the plateau:**

    Answer: The rate of photosynthesis increases proportionally with light intensity.

    [2 marks]

16. **Explain why plotting a graph is useful in analyzing experimental data.**

    Answer: It visually represents trends, makes it easier to identify relationships, and highlights anomalies in data.

    [3 marks]

17. **If the experiment were conducted with a red-light source instead of white light, how would the rate of photosynthesis change? Justify your answer.**

    Answer: The rate would increase because chlorophyll absorbs red light effectively, enhancing photosynthesis.

    [4 marks]

18. **A student suggested testing the experiment in low-temperature conditions (10°C). Predict how temperature might affect the rate of photosynthesis**

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and the shape of the graph.

Answer: The rate of photosynthesis would decrease because enzyme activity slows at low temperatures. The graph would show a flatter curve with a lower plateau.

[4 marks]

19. **Why is it important to use a healthy, green plant for this experiment?**

    Answer: Healthy plants have active chloroplasts and sufficient chlorophyll, ensuring accurate results for photosynthesis experiments.

    [3 marks]

20. **If sodium bicarbonate were added to the water, predict how the graph might differ and explain your reasoning.**

    Answer: The rate of photosynthesis would increase, and the plateau would occur at a higher rate because the added bicarbonate increases carbon dioxide availability, a key reactant in photosynthesis.

    [4 marks]

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APPENDIX I

Marking Scheme for SPSAT (Pretest)

1. Identify the parts labelled I to VIII

   I: Leaf

   II: Oxygen

   III: Water

   IV: Carbon dioxide

   V: Sodium bicarbonate solution

   VI: Beaker

   VII: Funnel

   VIII: Aquatic plant (e.g., Elodea)

   [8 marks]

2. What is the aim of the experiment?

To demonstrate the process of photosynthesis and the release of oxygen as a by-product.

[1 mark]

3. Name two factors that can affect the results of the experiment?

   - **Light intensity**
   - **Carbon dioxide concentration**

   [2 marks]

4. What type of liquid is used in the part labelled V?

   Sodium bicarbonate solution.

   [1 mark]

5. Name one organism that can be used in the part labelled VIII.

   Elodea (an aquatic plant). **[1 mark]**

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6. What process produced the substance labelled IV?

   Photosynthesis.

[1 mark]

7. Explain the test that confirms the nature of the substance labelled II.

   Collect the gas in a test tube and insert a glowing splint. If the splint relights, the gas is confirmed to be oxygen.

[2 marks]

8. Suggest a suitable control for the experiment.

   Use the same setup but keep it in the dark to ensure no photosynthesis occurs.

[1 mark]

9. Write a balanced chemical equation of the biological process involved in the experiment.

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

[2 marks]

10. Using a scale of 1cm to 10 units on the y-axis and 1cm to 5 units on the x-axis, plot a graph showing the rate of photosynthesis on the y-axis and light intensity on x-axis.

[8 marks]

11. From the plotted graph in (10), explain briefly the effect of light intensity on the rate of photosynthesis.

The rate of photosynthesis increases with light intensity up to a saturation point, after which it remains constant regardless of further increases in light intensity.

[3 marks]

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12. List three other factors that affect the rate of photosynthesis.

- **Carbon dioxide concentration**
- **Temperature**
- **Water availability**

[3 marks]

13. Make a drawing 8cm to 10cm of the chloroplast and label fully.

[6 marks]

14. Describe the role of chloroplasts in plant cells and explain why they are essential for photosynthesis.

Chloroplasts contain chlorophyll, which traps light energy from the sun. They are the site of photosynthesis where light-dependent reactions produce ATP and NADPH, and the Calvin cycle converts carbon dioxide into glucose. Chloroplasts are essential for converting solar energy into chemical energy stored in glucose, which supports life.

[4 marks]

15. What is the purpose of placing the fresh leaves in boiling water before testing for starch?

To kill the cells and stop all enzymatic activities.

[1 mark]

16. Predict what would happen if the leaves were not placed in cold ethanol after boiling. How would this affect the results of the starch test?

The chlorophyll would not be removed, making it difficult to observe the color change with iodine solution.

[2 marks]

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17. Why is it important to rinse the leaves with water after removing them from the ethanol?

    To soften the leaf and remove excess ethanol. **[1 mark]**

18. If a leaf turns blue-black after adding iodine solution, what can you infer about the presence of starch in that leaf?

    Starch is present in the leaf.

    [1 mark]

19. Describe the appearance of a leaf before and after it has been treated with iodine solution. What differences do you observe?

    Before: The leaf appears green due to chlorophyll. After: The leaf turns blue-black in areas where starch is present.

    [2 marks]

20. If you were to perform the starch test on a leaf kept in complete darkness for 24 hours, what do you predict the result would be? Explain your reasoning.

    The leaf would not turn blue-black because it would not contain starch. In darkness, photosynthesis does not occur, and stored starch is used up for respiration.

    [4 marks]

21. Why do we use a white tile or paper when conducting the starch test? How does this aid in observation?

    A white tile provides a clear, contrasting background, making it easier to observe any color change.

22. If a leaf does not change color after adding iodine solution, what inference can you make about the presence of starch in that leaf?

    The leaf does not contain starch. **[1 mark]**

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23. What would happen if iodine solution is added to a leaf that has been exposed to strong sunlight for several hours? Predict the possible outcome and explain your reasoning.

    The leaf would turn blue-black because sunlight enables photosynthesis, leading to starch production.

    [2 marks]

24. During the experiment, what changes did you observe in the iodine solution after it was added to the leaf? How do these changes relate to the presence or absence of starch?

    The iodine solution turns blue-black in the presence of starch and remains yellow-brown if starch is absent.

    [2 mark]

25. How would you classify a leaf that exhibits a faint color change after the starch test? What might this indicate about the amount of starch present in the leaf?

    The leaf contains a small amount of starch, indicating limited photosynthetic activity.

    [2 marks]

26. What factor is the student varying?

    Light intensity.

    [1 mark]

27. Assume that the student places plant 'A' in indirect sunlight for two days. After this time, the student tested one leaf from the plant for starch content. What would you expect the results to be?

    The leaf would show a reduced or no blue-black color, as low light intensity would limit photosynthesis and starch production. **[2 marks]**

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28. Classify the role of the factor in photosynthesis as "essential," "beneficial but not essential," or "not necessary." Justify your classification with evidence from the experiment.

    Essential: Light is necessary for photosynthesis, as it provides the energy required for the light-dependent reactions.

    [2 marks]

29. What is the role of the sodium hydroxide in the experiment?

    Sodium hydroxide absorbs carbon dioxide, creating a control condition to test its necessity for photosynthesis.

    [1 mark]

30. Make a prediction about the effect of carbon dioxide on starch production in plants.

    Increased carbon dioxide levels enhance starch production, as carbon dioxide is a key reactant in the Calvin cycle of photosynthesis.

    [2 marks]

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APPENDIX J

CRONBACH'S ALPHA RELIABILITY OF SPSAT

```
RELIABILITY
  /VARIABLES=Test Retest
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /SUMMARY=TOTAL.
```

Reliability

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	50	100.0
	Excluded[a]	0	.0
	Total	50	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.904	2

NB: A Cronbach's alpha of 0.90 indicates a high level of internal consistency reliability for students between students' SPSAT scores on the first and second administrations. As a result, the SPSAT has a strong coefficient of internal consistency and is therefore reliable for use in the research.

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APPENDIX K

TEST-RETEST RELIABILITY OF PhPT

CORRELATIONS

/VARIABLES=Test Retest

/PRINT=TWOTAIL NOSIG FULL

/STATISTICS DESCRIPTIVES

/MISSING=PAIRWISE.

Descriptive Statistics

	Mean	Std. Deviation	N
Test	33.38	4.686	50
Restest	35.00	4.486	50

Correlations

		Test	Restest
Test	Pearson Correlation	1	.836**
	Sig. (2-tailed)		.000
	N	50	50
Restest	Pearson Correlation	.836**	1
	Sig. (2-tailed)	.000	
	N	50	50

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

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APPENDIX L

CRONBACH'S ALPHA RELIABILITY OF PhPT

```
RELIABILITY
  /VARIABLES=Test Retest
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /SUMMARY=TOTAL MEANS.
```

Reliability

Case Processing Summary			
		N	%
Cases	Valid	50	100.0
	Excluded[a]	0	.0
	Total	50	100.0
a. Listwise deletion based on all variables in the procedure.			

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.910	.911	2

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APPENDIX M

ITEM ANALYSIS

ITEM	FACILITY INDEX (F.I)	DESCRIMINATION INDEX (D.I)	REMARKS
1	0.62	0.50	Accepted
2	0.57	0.43	Accepted
3	0.68	0.52	Accepted
4	0.46	0.50	Accepted
5	0.57	0.36	Accepted
6	0.82	-0.19	Rejected
7	0.54	0.36	Accepted
8	0.32	0.53	Accepted
9	0.43	0.28	Modified
10	0.68	0.56	Accepted
11	0.25	0.36	Modified
12	0.65	0.57	Accepted
13	0.21	-0.17	Rejected
14	0.29	0.43	Modified
15	0.38	0.65	Accepted
16	0.7	0.27	Modified
17	0.61	0.51	Accepted
18	0.54	0.50	Accepted
19	0.36	0.37	Accepted
20	0.82	0.18	Rejected

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21	0.47	0.57	Accepted
22	0.39	0.43	Accepted
23	0.24	0.72	Modified
24	0.15	0.19	Rejected
25	0.43	0.57	Accepted
26	0.39	0.61	Accepted
27	0.57	0.43	Accepted
28	0.38	0.73	Modified
29	0.2	0.23	Modified
30	0.18	0.36	Rejected
31	0.39	0.64	Accepted
32	0.5	0.57	Accepted
33	0.43	0.43	Accepted
34	0.57	0.36	Accepted
35	0.32	0.57	Accepted
36	0.54	0.64	Accepted
37	0.39	0.57	Accepted
38	0.57	0.29	Modified
39	0.32	0.50	Accepted
40	0.54	0.36	Accepted
41	0.58	0.44	Accepted
42	0.42	0.64	Accepted
43	0.43	0.28	Modified
44	0.28	0.19	Rejected

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45	0. 44	0.53	Accepted
46	0.22	0.72	Modified*
47	0.17	0.29	Rejected
48	0.40	0.54	Accepted
49	0.76	0.18	Rejected
50	0.27	0.29	Modified*

KEY FOR F.I.:

0.81 – 1.00 - Very Easy - Rejected

0.71 – 0.80 - Easy - Modified

0.30 – 0.70 - Moderate - Accepted

0.20 – 0.29 - Difficult - Modified

0.00 – 0.19 - Very Difficult - Rejected

KEY FOR D.I.:

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

0.00 - No Discrimination - Rejected

0.01 – 0.19 Very Low Positive Values - Rejected

0.20 – 0.29 - Low Positive Values - Modified

0.30 – 0.70 - Moderately Positive Values - Accepted

0.71 – 0.80 - High Positive Values - Modified

0.81 – 1.00 - Very High Positive Values - Rejected

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APPENDIX N

TEST-RETEST RELIABILITY OF SPSAT

```
CORRELATIONS
  /VARIABLES=Test Retest
  /PRINT=TWOTAIL NOSIG FULL
  /STATISTICS DESCRIPTIVES
  /MISSING=PAIRWISE.
```

Correlations

Descriptive Statistics			
	Mean	Std. Deviation	N
Test	58.70	2.971	50
Restest	62.72	2.850	50

Correlations			
		Test	Restest
Test	Pearson Correlation	1	.826**
	Sig. (2-tailed)		.000
	N	50	50
Restest	Pearson Correlation	.826**	1
	Sig. (2-tailed)	.000	
	N	50	50
**. Correlation is significant at the 0.01 level (2-tailed).			

NB: The correlation coefficient (r = 0.83) shows a significant positive correlation between students' SPSAT scores on the first and second administrations. As a result, the SPSAT is very stable and reliable for use in this research

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APPENDIX O

WEEK ONE

Method of Teaching: 5Es Instructional Strategy

Subject: Biology

Group: Experimental

Class: SHS 2

Number of Students: 50

Topic: Photosynthesis

Duration: 120 minutes (Double Period)

Reference Materials:

Fast-Truck Approach to Biology, College biology (A1 series)

Instructional Materials:

Fresh leaves, iodine solution, test tubes, boiling water, charts illustrating photosynthesis, students' worksheet.

Objectives:

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

i. Define photosynthesis correctly in their own words;

ii. Explain the basic process of photosynthesis;

iii. Identify the raw materials and products of photosynthesis;

iv. Perform an experiment to demonstrate the presence of starch in a leaf;

v. Mention the importance of photosynthesis to plants and animals;

vi. Demonstrate critical thinking and teamwork during practical activities.

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Previous Knowledge:

Students are familiar with basic plant structures and the concept of energy transformation in living organisms.

Presentation:

Teacher organizes students into 10 groups of 5 students each, highlights the topic to be learned, and emphasizes the need for each student to participate fully in classroom activities.

Phase 1: ENGAGEMENT

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

i. What are the basic parts of a plant?

ii. What is the primary function of leaves?

iii. How do plants obtain their food?

Phase 2: EXPLORATION

Teacher presents two activities to be carried out by students and uses certain conceptual questions to encourage and focus students' exploration.

ACTIVITY 1

Aim: To Demonstrate the Presence of Starch in a Leaf

Materials: Fresh leaf, boiling water, iodine solution, test tubes, beaker.

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Procedure:

1. Boil the leaf in water for a few minutes to kill it.
2. Place the leaf in alcohol and heat it gently until it decolorizes.
3. Rinse the leaf in warm water to soften it.
4. Add a few drops of iodine solution to the leaf.

Observations: Note any color change.

Conceptual Questions:

i. What is the color change observed?

ii. What does this indicate about the presence of starch in the leaf?

ACTIVITY 2

Aim: To Illustrate the Basic Process of Photosynthesis Using a Chart

Materials: Chart illustrating photosynthesis, worksheet.

Procedure: Study the chart and label the parts involved in photosynthesis.

Conceptual Questions:

i. What are the raw materials needed for photosynthesis?

ii. What are the products of photosynthesis?

iii. Where does photosynthesis take place in the plant?

Phase 3: EXPLANATION

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

i. What do you understand by the term 'photosynthesis'?

ii. What are the main stages of photosynthesis?

iii. Why is photosynthesis important for plants and animals?

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

Definition of Photosynthesis:

Photosynthesis is the process by which green plants use sunlight to synthesize foods with the aid of chlorophyll, primarily glucose, from carbon dioxide and water. Oxygen is released as a byproduct.

Equation of Photosynthesis:

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

Importance of Photosynthesis:

1. Provides oxygen necessary for respiration.
2. Produces glucose which serves as energy and structural material for plants.
3. Forms the basis of the food chain.

Phase 4: ELABORATION

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

ACTIVITY 3

Aim: To Demonstrate the Effect of Light on Photosynthesis

Materials: Potted plant, black paper, scissors.

Procedure:

1. Cover a part of a leaf with black paper.
2. Place the plant in sunlight for a few hours.
3. Remove the leaf and test it for starch as done in Activity 1.

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Conceptual Questions:

i. What difference do you observe between the covered and uncovered parts of the leaf?

ii. What conclusion can you draw about the role of light in photosynthesis?

Phase 5: EVALUATION

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

i. Define photosynthesis in your own words.

ii. Briefly explain the main stages of photosynthesis.

iii. Describe an experiment to show the presence of starch in a leaf.

iv. Mention the importance of photosynthesis to plants and animals.

v. Outline the raw materials and products of photosynthesis.

WEEK TWO

Method of Teaching: 5Es Instructional Strategy

Subject: Biology

Group: Experimental

Class: SHS 2

Number of Students: 50

Topic: Photosynthesis - Light and Dark Reactions

Duration: 120 minutes (Double Period)

Reference Materials:

Fast-Truck Approach to bioogy, College Biology (A1 series).

Instructional Materials:

Diagrams of chloroplast, models of light and dark reactions, worksheets.

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Objectives:

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

i. Differentiate between light and dark reactions;

ii. Describe the role of chlorophyll in photosynthesis;

iii. Explain the significance of ATP and NADPH in photosynthesis;

iv. Perform a simple experiment to demonstrate light reaction;

v. Work collaboratively in groups to analyze experimental data.

Previous Knowledge: Students have basic knowledge of photosynthesis and its importance.

Presentation:

Teacher organizes students into 10 groups of 5 students each, highlights the topic to be learned, and emphasizes the need for each student to participate fully in classroom activities.

Phase 1: ENGAGEMENT

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

i. What are the raw materials of photosynthesis?

ii. What products are formed during photosynthesis?

iii. Why is sunlight important for plants?

Phase 2: EXPLORATION

Teacher presents two activities to be carried out by students and uses certain conceptual questions to encourage and focus students' exploration.

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ACTIVITY 1

Aim: To Demonstrate the Role of Light in Photosynthesis (Light Reaction)

Materials:

- Fresh spinach leaves or an aquatic plant like Elodea
- A glass beaker or jar
- Sodium bicarbonate (baking soda)
- A lamp with a bright light source (incandescent or LED bulb)
- Test tubes
- Water
- Alcohol (ethanol)
- Iodine solution
- Petri dish
- Mortar and pestle
- Cheesecloth or coffee filter
- Ice bath

Procedure:

1. **Preparation of Chloroplast Extract:**
   - Place fresh spinach leaves in a mortar.
   - Add a small amount of cold water and grind the leaves to make a green slurry.
   - Filter the slurry through cheesecloth or a coffee filter into a test tube to obtain the chloroplast extract.
2. **Setting Up the Experiment:**
   - Fill a beaker or jar with water and add a pinch of sodium bicarbonate to provide a source of carbon dioxide.
   - Pour the chloroplast extract into a petri dish.

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- Place the petri dish in the ice bath to keep the extract cool and prevent enzyme degradation.

3. **Exposure to Light:**

- Position the petri dish containing the chloroplast extract under the lamp. Make sure the light source is directly above the extract.
- Leave another petri dish with chloroplast extract in the dark as a control.
- Allow both dishes to sit for 15-20 minutes.

4. **Observation of Light Reaction:**

- After the exposure period, observe any changes in the chloroplast extract under the light and in the dark.
- The extract under the light should show more bubbling due to the production of oxygen, indicating the occurrence of the light reaction.

Conceptual Questions:

1. What do the bubbles represent?
2. What does this indicate about the role of light in photosynthesis?
3. Why is it important to keep the chloroplast extract cool during the experiment?
4. What role does sodium bicarbonate play in the experiment?

ACTIVITY 2

Aim: To Model the Light and Dark Reactions of Photosynthesis

Materials: Diagrams of chloroplast, models, worksheets.

Procedure: Study the models and diagrams, then answer the questions on the worksheet.

Conceptual Questions:

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i. Where do the light and dark reactions take place within the chloroplast?

ii. What are the main products of the light reaction?

iii. How are these products used in the dark reaction?

Phase 3: EXPLANATION

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

i. What are the two main stages of photosynthesis?

ii. What is the role of chlorophyll in the light reaction?

iii. How is ATP generated during photosynthesis?

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

Light Reaction:

Occurs in the thylakoid membranes of chloroplasts where light energy is converted into chemical energy (ATP and NADPH).

Dark Reaction (Calvin Cycle):

Occurs in the stroma of chloroplasts where ATP and NADPH are used to fix carbon dioxide into glucose.

Phase 4: ELABORATION

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

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ACTIVITY 3

Aim: To Demonstrate the Importance of Chlorophyll in Photosynthesis

Materials: Variegated leaf, iodine solution, test tubes, beaker.

Procedure:

1. The leaf of a variegated Pelargonium is dropped in boiling water to kill and preserve it.
2. The leaf is left for 10 minutes in hot ethanol in a boiling tube to remove chlorophyll.
3. The leaf is dipped in boiling water to soften it.
4. The leaf is spread out in a Petri dish and covered with iodine solution.

Conceptual Questions:

i. What parts of the leaf tested positive for starch?

ii. What does this indicate about the presence of chlorophyll and photosynthesis?

Phase 5: EVALUAT

ION

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

i. Differentiate between light and dark reactions.

ii. Describe the role of chlorophyll in photosynthesis.

iii. Explain the significance of ATP and NADPH in photosynthesis.

iv. Perform an experiment to demonstrate light reaction.

v. Discuss the importance of teamwork in scientific experiments.

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WEEK THREE

Method of Teaching: 5Es Instructional Strategy

Subject: Biology

Group: Experimental

Class: SHS 2

Number of Students: 50

Topic: Factors Affecting Photosynthesis

Duration: 120 minutes (Double Period)

Reference Materials: Fast-Truck Approach to Biology, College Biology (A1)

Instructional Materials: potted plants, worksheets.

Objectives:

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

i. Identify factors affecting the rate of photosynthesis;

ii. Explain how light intensity, temperature, and carbon dioxide concentration influence photosynthesis;

iii. Perform experiments to investigate the effects of these factors;

iv. Analyze experimental data to draw conclusions;

v. Demonstrate effective communication skills during group discussions.

Previous Knowledge:

Students understand the basic process and stages of photosynthesis.

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Presentation:

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

Phase 1: ENGAGEMENT

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

i. What are the necessary conditions for photosynthesis to occur?

ii. How does the availability of sunlight affect plant growth?

iii. Why is temperature important for biological processes?

Phase 2: EXPLORATION

Teacher presents two activities to be carried out by students and uses certain conceptual questions to encourage and focus students' exploration.

ACTIVITY 1

Aim: To Investigate the Effect of Light Intensity on Photosynthesis

Materials: Light meter, potted plant, beaker, water.

Procedure:

1. Take the potted plant and keep it in a dark place for 24hrs so that the leaves get destarched.

2. Cover a part of one of its leaves with the strip of black paper. Make sure that you cover both the sides of the leaf.

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3. Now place this plant in sunlight for 3—4 hours.

4. Pluck the selected covered leaf and remove the black paper covering it.

5. Place this leaf in the beaker containing water and boil it for about 10 minutes.

6. Take out the leaf and now boil it in alcohol, using the water bath, for 10 minutes. This removes the chlorophyll.

7. Take out the leaf and wash it under running water.

8. Place this leaf in the Petri dish and put a few drops of iodine solution on it.

Conceptual Questions:

Why did the covered parts of the leaf not turn blue-black?

What does the presence of starch in the exposed parts of the leaf indicate?

Why is light necessary for photosynthesis?

Phase 3: EXPLANATION

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

i. What factors influence the rate of photosynthesis?

ii. How do light intensity and temperature affect photosynthesis?

iii. Why is it important to control these factors in agricultural practices?

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

Factors Affecting Photosynthesis:

Light Intensity: Higher light intensity increases the rate of photosynthesis up to a certain point.

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Temperature: Photosynthesis rate increases with temperature until an optimum level, after which it declines.

Carbon Dioxide Concentration: Higher CO2 concentration can enhance the rate of photosynthesis.

Phase 4: ELABORATION

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

ACTIVITY 2

Aim: To Investigate the Effect of Carbon Dioxide Concentration on Photosynthesis

Materials: pH meter, potted plant, beaker, sodium bicarbonate solution.

Procedure:

1. Destarch the leaves of potted plant by placing them in a dark place for about 24hrs. Test for starch to ensure no starch is present.
2. Enclose one leaf (A) in a glass flask containing soda lime or potassium hydroxide.
3. Enclose a send leaf (B) in a similar flask but without the soda lime as a control experiment.
4. Put the set-up in sunlight for about three hours and test for presence of starch.

Observation:

The leaf from Plant B (control setup) should turn blue-black, indicating the presence of starch, as it had access to CO_2.

The leaf from Plant A (experimental setup) should remain a pale color, indicating no starch production, as it did not have access to CO_2.

Conceptual Questions to Discuss:

1. Why did the leaf from Plant B turn blue-black?

The leaf turned blue-black because it had access to CO_2, which is necessary for photosynthesis, resulting in starch production.

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2. Why did the leaf from Plant A not turn blue-black?

The leaf did not turn blue-black because it lacked access to CO2, and therefore, photosynthesis could not occur, resulting in no starch production.

3. What does this experiment demonstrate about the necessity of CO2 for photosynthesis?

This experiment demonstrates that CO2 is essential for the photosynthetic process, as it is a key reactant in the production of glucose and starch.

Phase 5: EVALUATION

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

i. Identify factors affecting the rate of photosynthesis.
ii. Explain how light intensity, temperature, and carbon dioxide concentration influence photosynthesis.
iii. Describe an experiment to investigate the effect of one factor on photosynthesis.
iv. Analyze experimental data to draw conclusions about photosynthesis.
v. Discuss the importance of controlling environmental factors in agriculture.

WEEK FOUR

Method of Teaching: 5Es Instructional Strategy

Subject: Biology

Group: Experimental

Class: SHS 2

Number of Students: 50

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Topic: Photosynthesis

Subtopics: Adaptation of Leaf for Photosynthesis, Importance of Photosynthesis, Experiment to Show that Oxygen is Given Off During Photosynthesis, Fate of Photosynthesis Products

Duration: 120 minutes (Double Period)

Reference Materials: Fast-Truck Approach to Biology, College Biology (A1 series).

Instructional Materials: Fresh leaves, charts of leaf structure, beakers, water plants (e.g., Elodea), test tubes, light source (lamp), aquatic plant setup, stopwatch, worksheets.

Objectives:

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

i. Describe the adaptations of leaves for photosynthesis;

ii. Explain the importance of photosynthesis;

iii. Conduct an experiment to show that oxygen is given off during photosynthesis;

iv. Discuss the fate of products of photosynthesis.

Previous Knowledge: Students have an understanding of the basic process of photosynthesis and the factors affecting it.

Presentation:

Teacher organizes students into 10 groups of 5 students each, highlights the topic to be learned, and emphasizes the need for each student to participate fully in classroom activities.

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Phase 1: ENGAGEMENT

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

i. How do you think leaves are adapted to capture sunlight?

ii. Why is photosynthesis vital for plants and animals?

iii. Can you guess what happens to the oxygen produced during photosynthesis?

Phase 2: EXPLORATION

Teacher presents three activities to be carried out by students and uses certain conceptual questions to encourage and focus students' exploration.

ACTIVITY 1: Adaptations of Leaf for Photosynthesis

Aim: To examine the structural adaptations of leaves for photosynthesis.

Materials: Fresh leaves from monots and dicot, charts or diagrams of leaf structure, hand lenses.

Procedure:

1. Observe the structure of fresh leaves using hand lenses.
2. Examine charts or diagrams showing internal leaf structure.
3. Identify and note the adaptations for photosynthesis, such as broad surface area, thin structure, chloroplasts, stomata, and vascular bundles.

Conceptual Questions:

i. What features of the leaf structure make it efficient for photosynthesis?

ii. How do stomata contribute to the photosynthetic process?

iii. Mention any two structural differences between the monocot and dicot leaves.

iv. Why do you think the lamina or leaf blades in both leaves are thin and flat?

v. What functions do the midrib and veins serve?

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ACTIVITY 2: Experiment to Show that Oxygen is Given Off During Photosynthesis

Aim: To demonstrate that oxygen is a byproduct of photosynthesis.

Materials: Water plant (e.g., spirogyra), beakers, test tubes, water, light source, sodium hydrocarbonate.

Procedure:

1. Fill a beaker with and add some pondweeds or spirogyra
2. A small amount of sodium hydrocarbonate (NaHCO3) may be added which decompose to add carbon dioxide.
3. Fit a funnel rested on a support over the weed and invert a test-tube filled with water over funnel. Place the set-up in bright sunlight.
4. After sometimes, bubble of colourless gas are formed on the pondweed and they rise collect in the test-tube. When sufficient gas has been collected in the test-tube, remove the test-tube closing with the thumb.
5. Test the nature of the gas by placing a glowing splint of wood into the gas in the tube
6. If the gas rekindles a glowing wooden splint, then the gas collected is oxygen.

Conceptual Questions:

i. What gas is collected in the test tube during the experiment?

ii. What evidence supports that photosynthesis is occurring in the plant?

ACTIVITY 3: Fate of Products of Photosynthesis

Aim: To discuss the uses of glucose and oxygen produced in photosynthesis.

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Materials: Worksheets, charts of plant and animal cells, case studies.

Procedure:

Review the chemical equation of photosynthesis.

Discuss how plants use glucose for energy, growth, and storage (as starch).

Discuss the role of oxygen in cellular respiration for plants and animals.

Analyze case studies where the fate of photosynthesis products is significant (e.g., in ecosystems, agriculture).

Conceptual Questions:

i. How do plants utilize the glucose produced during photosynthesis?

ii. Why is oxygen important for both plants and animals?

Phase 3: EXPLANATION

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

i. How are leaves adapted to maximize photosynthesis?

ii. What happens to the oxygen produced during photosynthesis?

iii. What are the end products of photosynthesis and their uses?

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

Adaptations of Leaves for Photosynthesis:

Broad Surface Area: Maximizes light absorption.

Thin Structure: Reduces diffusion distance for gases.

Chloroplasts: Contain chlorophyll for light absorption.

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Stomata: Allow gas exchange.

Vascular Bundles: Transport water and nutrients.

Importance of Photosynthesis:

1. Provides energy for plant growth and development.
2. Essential for respiration in most living organisms.
3. Reduces atmospheric CO2 levels.

Fate of Photosynthesis Products:

Glucose: Used for energy, growth, and stored as starch.

Oxygen: Released into the atmosphere and used for respiration.

Phase 4: ELABORATION

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

Further Activity:

Aim: To explore the ecological significance of photosynthesis.

Materials: Charts of food webs, ecosystem models, worksheets.

Procedure:

1. Examine food web charts to understand the flow of energy from plants to other organisms.
2. Discuss the role of photosynthesis in maintaining the balance of oxygen and carbon dioxide in the atmosphere.
3. Analyze the impact of photosynthesis on global ecosystems.

Phase 5: EVALUATION

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

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i. Describe the structural adaptations of leaves for photosynthesis.

ii. Explain why photosynthesis is essential for life on Earth.

iii. Conduct and explain an experiment to show that oxygen is given off during photosynthesis.

iv. Discuss the fate of the products of photosynthesis.