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USING CONCEPT MAPS TO IMPROVE STUDENTS' ACHIEVEMENT IN SELECTED BIOLOGY TOPICS

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DECLARATION

STUDENT'S DECLARATION

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

SIGNATURE: …………………………………………….

DATE: ………………………………………………….

SUPERVISOR'S DECLARATION

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

DR. CHARLES KWESI KOOMSON (SUPERVISOR)

SIGNATURE: ………………………………………..

DATE: ……………………………………………….

DEDICATION

I dedicate this work to the Almighty God for his faithfulness and mercies throughout this programme. I also dedicate it to my industrious Head of Department of Science Education UEW, Dr. Charles Kwesi Koomson, my parents. Williams Amoah and Mary Amankwaa, my lovely wife Mercy Akua Gyinaa and daughters Erica and Clara. Finally, to all the wonderful people in my life for their encouragement and support. I could not have come this far without you all.

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LIST OF ABBREVIATIONS

CM: Concept Map

ICM: Instructional Concept Map

WASSCE: West African Senior Secondary Certificate Examination

SHS: Senior High School

MOE: Ministry of Education

GES: Ghana Education Service

SAT: Student Achievement Test

SPSS: Statistical Package for the Social Sciences

HSD: Honest Significant Difference

ABSTRACT

This study examined the influence of concept mapping teaching method on the academic achievement of selected biology students in Osei-Bonsu SHS. The objectives of the research were to determine the; 1. Effect of concept mapping teaching method on senior high school students' academic achievement in biology, 2. Effect of concept mapping on senior high school students' retention ability and 3. Influence of gender on senior high school students' academic achievement when taught biology using the concept mapping method. The action research approach was used, the target population for the study included all senior high schools in the Bono-East Region of Ghana. The accessible population, however, comprised senior high schools in the Nkoranza-North District of the Bono-East Region. An intact class of forty-two final year science students were purposively selected for the study. Data were collected using pre- and post-intervention tests and analysed statistically using the statistical package for social sciences software. The study found that concept mapping approach to teaching had a significant ($p < 0.05$) impact on the performance of students in biology. Also, concept mapping teaching approach was found to have a significant ($p < 0.05$) impact on students' retention ability. It was recommended that curriculum developers should incorporate concept mapping strategy into curriculum guidelines for meaningful and higher order learning.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter outlines the background to the study, the factors that necessitated the study. The statement of the problem was discussed and the purpose of the study stated. Objectives of the study and the research questions were presented. A discussion of the significance of the study, together with the delimitations and limitations of the study were outlined. Ensuing that is the definition of key terms and the organization of the study for the chapters that follow.

1.1 Background to the Study

Over the years, researchers (Ajaja, 2011; Aziz & Rahman, 2014) have been investigating why some learners acquire a deep, meaningful understanding of materials studied, whereas others have only a superficial grasp of the information presented. Often the latter kind of students may have high school grades and high standardized test scores (Bahar, 2010). What appeared to underlie the differences in these two groups of students according to Novak (2010) was the differences in the way they approached learning of subject matter. Novak (2010) developed concept mapping strategy based on the theoretical foundation laid down by educational psychologists. The underlying basis of the theory is that meaningful human learning occurs when new knowledge is consciously and purposively linked to an existing framework of prior knowledge (Novak, 2010). Furthermore, Novak (2010) mentioned that the mind organises information in a hierarchical top-down fashion from higher level skills to the lower-level skills. While, in rote (or memorised) learning, new concepts are added to the learner's framework in an arbitrary and verbatim way, producing a weak and unstable structure that quickly degenerates. The result of meaningful learning is a change in the way individuals experience the world. It is seen that the students who learn by rote according to Novak (2010) can recall the new information but they cannot apply the knowledge in other situations. To give an organized body of content in a meaningful way, keeping in mind the cognitive map of the learner, simple ideas is presented first to the students followed by complex ideas joined in hierarchical manner so that proper learning can take place in sequential and integrated manner (Novak, 2010).

Concept mapping is a graphical tool for organizing and representing knowledge in networks of concepts and linking statements about a problem or subject (Novak & Canas, 2006). Concept maps are useful tools in representing the structure of knowledge in a form that is psychologically compatible with the way in which human beings construct meaning (Cheema & Mirza, 2013). According to Hall (2002), concept mapping increases recall of information in instructions in biology subject. Kinechin (2000) recommended the use of concept mapping on instruction and learning in secondary school biology education. Nowruzi, Khiabani and Nafissi (2010) found that the beginning stage of drawing concept maps not only needs active participation of the learner in the learning process but also paves the way on their understanding of a specific learning area. As a result, such information about learners' understanding empowers facilitators to determine learners' cognitive deficiencies and provide corrective feedback. Lambiotte and Dancereau (2001) observed that the students that made concept maps have a broader knowledge base and, therefore, abler to solve problems compared to those students that learned by rote memorization. The authors also found that the students with low prior knowledge learned better with concept mapping than those taught with lecture method. Concept mapping has also proved to be a useful vehicle to fill the usual gap between theories and practice (Sutherlang & Katz, 2005).

Based on the numerous benefits of concept maps to the teaching and learning of biology outlined in the literature, it has become necessary to use concept maps to aid his students to understand some selected concepts in biology.

1.2 Statement of the Problem

Educational researchers (Ajaja, 2011; Aziz & Rahman, 2014) have sought to find out why some learners acquire a deep, meaningful understanding of materials studied, whereas others have only a superficial grasp of the information presented. Generally, pupils memorize the content and reproduce the same to pass the examination (Dhaaka, 2012). In such an environment students' academic achievement, cannot be attained: Often this kind of learning leads to students' poor academic achievement (Asan, 2007). Students' poor academic achievement has been a focus of many studies examining the effects of interaction pattern on learning outcomes (Orji & Ebele, 2006). However, the situation does not seem to be improving. A thorough analysis of the biology WASSCE results of Osei-Bonsu senior high school over five years (2016-2020) revealed that students' performance in biology kept declining. Many factors were reported to contribute to the poor academic achievement of students in biology (Asan, 2007). Orji and Ebele (2006) attributed students' poor performance to ineffective methods of biology instruction adopted by senior high school teachers; they recommended the use of concept maps to improve students' academic performance in biology. In effect, this study sought to use concept maps to improve students' academic achievement in selected biology topics.

1.3 Purpose of the Study

The purpose of this study was to improve upon the academic achievement of senior high school students in selected biology topics using concept maps. The selected biology topics include cellular respiration, photosynthesis, and transport in plants.

1.4 Objectives of the Study

The objectives of this study were to determine the:

1. Effect of concept mapping teaching method on senior high school students' academic achievement in biology
2. Effect of concept mapping on senior high school students' retention ability.
3. Influence of gender on senior high school students' academic achievement when taught biology using the concept mapping method.

1.5 Research Questions

This study sought answers to the following questions:

1. What is the effect of concept mapping teaching method on senior high school students' academic achievement in biology?
2. What is the effect of concept mapping on senior high school students' retention ability?
3. What is the influence of gender on senior high school students' academic achievement when taught biology using the concept mapping method?

1.6 Null Hypotheses

Three hypotheses tested at 0.5 level of significance, guided the study.

H_{O1}. There is no statistically significant difference between students' academic achievement in biology before and after the use of concept mapping method to teach biology.

H_{O2}. The mean achievements of students on the pre-intervention test, post-intervention test and the retention test are the same.

H_{O3}. There is no statistically significant difference between the achievements of male and female senior high school students on the post-intervention test when biology was taught using concept mapping method of teaching.

1.7 Significance of the Study

- The academic performance in biology, of students who participated in this study may be improved.
- The findings from this study may motivate other biology teachers in the school where the study is conducted to espouse concept mapping teaching method to enhance the academic achievement of their students.
- Finally, the study may contribute to existing literature on the use of concept mapping in biology education.

1.8 Limitations of the Study

This study was limited by inadequate finances and logistics; hence more students were not included in the sample. Also, test anxiety on the part of the students could possibly affect their scores on the pre-intervention and post-intervention tests. To minimise the effect of test anxiety, the research participants were made aware that the outcomes of the tests are not for any academic purposes, but solely for research purposes.

1.9 Delimitations of the Study

This study was conducted in Osei-Bonsu senior high school. Only final year science students were sampled to participate in the study, and the study focused only on the following concepts in biology: cellular respiration, photosynthesis, and transport in plants. The scope of the study had been narrowed down to final year students only because they had already covered these topics in biology.

1.10 Definition of Terms

Some terms have been used in this study, that may have a different contextual meaning. Those terms are defined at this stage of the study.

Concept: Mouton (1996) defines a concept as the most elementary symbolic construction by means of which people classify or categorise reality or make sense and attribute meaning to their world.

Concept Mapping: Concept mapping is a graphical tool for organizing and representing knowledge in networks of concepts and linking statements about a problem or subject (Novak & Canas, 2006).

Students Achievement: The academic output of students based on test scores and oral feedback.

Teaching Approach: The totality of teaching strategies espoused by a teacher to attain teaching goals and objectives.

1.11 Organisation of the Study Report

This study is organized into five chapters. Chapter one has already been discussed. Chapter two comprises the review of related literature. It begins with an overview of the chapter and then a review of related literature under various strands. Chapter three consists of the research methodology. It is divided in to the overview, the design of the study, population and sampling procedure, instrumentation, the validity of the instruments, the reliability of the instruments, data collection, data analysis, pre-intervention findings, intervention, post-intervention, and implementation. Chapter four contains presentation and analysis of results. Chapter five covers the summary of findings, conclusion, recommendations and suggestion for further study, references, and appendices.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter of the study reviewed literature related to the study. The literature was reviewed under various strands. The purpose of the review was to explore findings from previous studies and see how they can be related to the current study. The conceptual framework, together with the theory that underpinned this study was also presented in this chapter.

2.1 Conceptual Framework

Introductory biology courses taught in senior high school form a cornerstone of undergraduate instruction. However, the predominantly used lecture approach fails to produce higher-order biology learning (Gardner & Belland, 2019). Research shows that active learning strategies, such as concept mapping learning methods can increase students' achievement, yet few biology instructors use all the identified active learning strategies (Gardner & Belland, 2019). Conceptual maps identify learning difficulties and provide activities that might influence teaching practices and subsequently students' learning (Gardner & Belland, 2019). Concept maps also provide a set of guiding principles that can be applied to various learning situations (Greer, 2018) the framework of concept maps is also able to provide a set of organising categories, presumed relationship among them and questions to prompt inquiry. It lays out a complex domain of interacting principles and concepts that affect teaching and learning of biology.

The framework for constructing a conceptual map is summarised in the figure below.

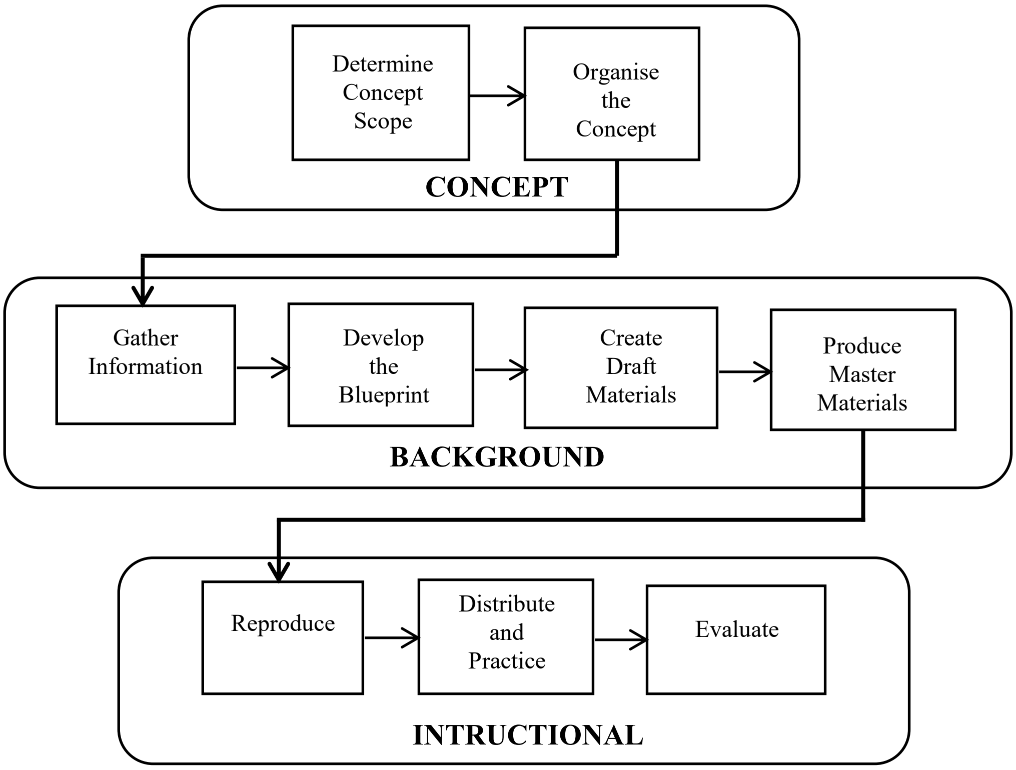

Figure 1: Conceptual Framework (adapted from Greer's model, 2018).

2.2 Concept Maps; What are They?

Concept maps can be considered both a cognitive and constructivist learning strategy. Based on Ausubel, Novak and Hanesian's (1986) view of cognitive learning, when learners create concept maps, they are focusing on determining relationships between and among concepts within their cognitive structures. They are also adding newly learned concepts to their existing cognitive structures. When the focus of the map is on depicting the relationships between concepts, a cognitive view of learning is operationalised. However, the focus of the map can also include linking concepts to lived experiences or linking lived experiences to each other. When the learner takes this approach, the map tends to be more of a constructivist learning strategy that can be used to foster reflective thinking and analysis.

Novak and Gowin (1984) described a concept map as “a schematic device for representing a set of concept meanings embedded in a framework of propositions”. In this view, we think and learn with concepts by linking new concepts to what we already know. In addition, concepts are stored hierarchically and differentiated as learning grows. Learning with concept maps means that the learner is making an intentional effort to link, differentiate and relate concepts to each other.

Ausubel (2000) and Ausubel, Novak and Hanesian (1986) believed that when we think and learn with concepts, we use three processes; subsumption, progressive differentiation and integrative reconciliation. In the subsumption process lower order concepts are subsumed under higher order concepts. This subsumption process creates a hierarchy of knowledge structures. In the progressive differentiation process concepts are broken down into finer and finer components. In this way, progressive differentiation is like an analysis process. Finally, integrative reconciliation is a process where the learner attempts to reconcile and link together concepts from the left side of the map to those on the right side of the map. This is like a synthesis process.

To create a concept map, the learner engages in an active process that uses these three ideas: First, the leaner identifies the most general concepts and places them at the top of the map. Second, the learner identifies more specific concepts that relate to the general concepts in some way. Third, the learner ties together the general and specific concepts with linking words that make sense to them. Finally, the learner actively looks for cross-linkages that tie concepts from one side of the map to the other.

Choosing linking words is one of the most difficult and yet, most important parts of creating a concept map. Whatever linking words the learner chooses will change the relationship between the concepts. To take a simple example, if as in Figure 2, a learner indicates that trees grow leaves one meaning is portrayed.

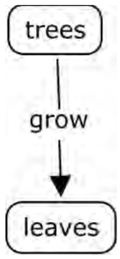

Figure 2: Sample linking word in concept map

However, if the learner changes the linking word and as in Figure 3 depicts that trees drop leaves a totally different meaning is portrayed.

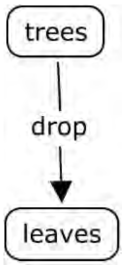

Figure 3: Changing linking word in a concept map

Thus, the linking words serve to create propositional statements that ultimately frame the meaning that the learner is attempting to convey or to construct. Concept maps can be created by hand with paper and pencil or they can be created using a few different computerised programmes designed for this purpose. With either method, what is most important is for the learner to be aware of the thinking processes that go into map creation and for the learner to identify and connect concepts with linking words that depict the meaning that is important to the learner.

2.3 Concept Maps

Concept Maps created by students can be used in several ways to facilitate meaningful learning. Novak and Gowin (2014) pointed out that Concept Maps are a kind of schematic summary of what students know. Concept maps provide a unique graphical view of how students organize, connect, and synthesize information. Novak and Gowin (2014) noted that the act of mapping is a creative activity, in which the learner must exert effort to clarify meanings, by identifying important concepts, relationships, and structure within a specified domain of knowledge. The activity fosters reflection on one's knowledge and understanding, providing a kind of feedback that helps students monitor their learning and, perhaps with assistance of teachers or peers, focus attention on learning needs. Lambiotte and Dancereau (2012) state that the students that viewed or made concept maps would have a broader knowledge base and therefore be more able to solve problems compared to those students that learned by rote memorization. They also found that the students with low prior knowledge learned better with concept mapping than the other. Cognitive structure and concept mapping are highly personal as everyone's knowledge is unique (Lambiotte & Dancereau, 2012). Hence, concept maps are idiosyncratic. There is no one ―correct" concept map (Lambiotte & Dancereau, 2012). However, this does not mean that all concept maps are correct: it is possible to identify errors, such as the absence of essential concepts or inappropriate relationship between concepts.

Although concept mapping fosters learning and understanding, beginners are easily overwhelmed by the demands of mapping. Chang *et al*. (2016) compared students' learning outcomes after either correcting worked-out concept maps with errors included, constructing their own concept maps after a training session, or constructing concept maps without training. The students learning by correcting concept maps achieved the best results in a learning test on text comprehension.

Students learning by constructing a map without training performed worst. It is, however, noteworthy that even after training students could still not perform as well as the students who learned by correcting concept maps. Similar advantages of studying worked-out maps in comparison to map construction were reported by Hauser *et al*. (2006). Edwards and Fraser (2013), produced a list to construct a concept map, which includes the following; choosing a passage from a science textbook, underlining the main concepts in this passage, listing all the concepts on paper, writing or printing the concepts on small cards or stickers so that the concepts can be moved around, placing the most general or all-inclusive concept on the top of the paper, arranging the concepts from top to bottom (from most general at the top to most specific at the bottom) so that a hierarchy is indicated, (in constructing this hierarchy) placing concepts next to each other horizontally if they are considered to have equal importance or value, relating concepts by positioning linking verbs and connecting words on directional arrows, supporting the concepts with examples, having members of a cooperative group critically analyse the concept map to improve on and further extend your ideas.

2.4 Advance Organizers

Ausubel (2000) moved the idea of advance organizers, and at times in the past, it seemed he was better known for this than for his theory of learning. His, and others', research shows that if one precedes a segment of instruction with a more general, more abstract segment of instruction on a topic to be studied (an ―advance organizer"), this can help the learner integrate the new details to be learned with existing relevant subsumers, thus facilitating meaningful learning. The advance organizer serves as a kind of ―cognitive bridge" that helps the learner to recognize existing relevant concepts and propositions she/he possesses and facilitating subsumption of the new information. The idea of advance organizers is not part of his theory of learning but rather an instructional strategy. Other psychologists have advanced similar ideas usually termed scaffolding learning (Horton *et al*., 2017). In either case, the goal is to help the learner assimilate new more explicit material to be learned into her/his cognitive structure. When an advance organizer is well planned, it should help the learner see relationships between some more general, relevant idea they already know and the more specific, more detailed concepts and propositions to be learned. In other words, a good advance organizer facilitates the subsumption of new relevant concepts and propositions. Concept maps may serve as very good advance organisers.

Many studies (Horton *et al*., 2017) have shown that the use of advance organizers significantly enhances meaningful learning of more detailed, relevant information. Some research studies have failed to show a positive effect for ―advance organizers," but in most of these cases, either there were inappropriate advance organizers or the achievement tests used did not require significant meaningful learning (Novak & Musonda, 2011). Testing only for recall of specific details is not likely to show the advantage of using an advance organizer, because there is no logical reason to suggest that an advance organizer could do anything to assist rote learning.

2.5 Concept Maps as Advance Organizers

In Ausubel's (1963) view, to learn meaningfully, students must relate new knowledge (concepts, proposition, rule, principles) to what they already know. Ausubel (1963) indicated that information or scientific concept is learned more easily if it is organized and sequenced logically. This gives rise to the term advance organizer. He proposes the notion of an advance organizer to help students link their ideas with new material or concepts. Advance organizers are concepts given to students prior to the material to be learned to provide a stable cognitive structure directing attention to what is important in the coming material; highlighting relationships among ideas that will be presented; and reminding the students of relevant information already in memory.

The organizers are introduced in advance of learning itself, and are also presented at a higher level of abstraction, generality, and inclusiveness. Ausubel (1963) emphasizes that advance organizers are different from overviews and summaries which simply emphasize key ideas and are presented at the same level of abstraction and generality as the rest of the material.

Advance organizer Concept Maps might be constructed by teachers or other experts. The Concept Map advance organizers can then be used in various ways as part of the classroom experience. They might be presented at the beginning of a textbook chapter or other instructional unit, or used as a guide for a lesson that is presented in a class. They might be used to present an overview of multimedia, with links to instructional materials associated with different topics. In theory, advance organizers are most effective if they make explicit the relationship among learned concepts that learners already know, thus providing a structure into which the new concepts can be integrated.

2.6 Concept Mapping

Concept Maps (CMs) are often constructed with reference to some question we seek to answer, which is called a focus question. It is the process of creating visual representation of knowledge that humans organize to communicate information. It is a general and an active teaching-learning strategy that can be used to help any individual or group to describe their ideas about some topic in a pictorial form (Schwendimann, 2015). This method of representing ideas is used to give a relationship between and among concepts, and identifies how they relate each other (Schwendimann, 2015). For many years CM has been constructed by hands using paper-pencil or chalk-board. But later the development of personal computer enabled the development of software programs that facilitated the construction of CMs and evolved into the current version of concept mapping tools (Novak & Canas, 2016). currently, software supported CM tools are popular in schools, universities, and governmental and non-governmental agencies. These tools are better than paper-pencil and chalk-board CM method because they allow the user to readily rearrange concepts and links to restructure the maps, and they help to link different sources such as photos, videos, graphs and notes to create graphical nodes representing concepts, and to connect nodes using lines and linking words to form a network of interrelated propositions that represent knowledge of a topic (Jena, 2012).

2.7 Development of Concept Map

Novak, Gowin and Johansen (2016) at Cornell University developed CM as an instructional method to assist students with science lessons. This was based on Ausubel's (1963) assimilation learning theory which states that learning takes place by the assimilation of new concepts and propositions into existing concept and propositional frameworks held by the learner. Hence, this knowledge structure as held by a learner is also referred to as the individual's cognitive structure. Novak and his team members have searched more manageable method for recording patterns of children's understanding of science concepts and this led to the development of concept map (Kinchin *et al*., 2018).

2.8 Construction Methods and Styles for Concept Maps

Numerous mapping systems have been developed that enable the graphical depiction of ideas and concepts, e.g., Concept Maps, Knowledge Maps, Mind Maps, Cognitive Maps, and Semantic Networks (Schwendimann, 2015). Concept Maps differ from these other superficially similar types of representations in a variety of ways. Essentially, Concept Maps are defined by:

- Their theoretical basis in Ausubel's Assimilation Learning theory and constructivist epistemology
- Their semi-hierarchical organization,
- The use of unconstrained and meaningful linking phrases, and
- The way concepts are defined.

2.9 Distinguishing Characteristics of Concept Maps

This section presents an elaboration of these distinguishing characteristics of Concept Maps, followed by some examples of Concept Maps. A standard method of Concept Map construction is presented along with variations, such as map facilitation procedures or interviews, and mapping by groups in collaborative settings, rather than by individuals.

2.9.1 Underlying theory

Concept Mapping is grounded in a sound cognitive learning theory, Ausubel's Assimilation Theory (Ausubel, 1963; Ausubel, Novak, & Hanesian, 1978). Assimilation theory posits that new knowledge can be learned most effectively by relating it to previously existing knowledge. Concept Maps may be viewed as a methodological tool of Assimilation theory that displays fundamental elements of the theory such as subsumption, integrative reconciliation and progressive differentiation.

2.9.2 Semi-hierarchical organization

The basic motivation for the hierarchical arrangement of concepts in Concept Maps comes from Ausubel's notion of subsumption, that more general, superordinate concepts subsume more specific, detailed concepts. This theoretical notion translates to an arrangement of concepts from those that are more general toward the top of the page, with those that are more specific or detailed distributed beneath. In practice, the concepts in Concept Maps are not arranged in a strict hierarchy, but are arranged in a semi-hierarchical manner. Concept Maps allow for the representation of non-hierarchical relationships or cross-links, as well as other types of non-hierarchical arrangements.

2.9.3 Labelled links

Another defining factor of Concept Maps is the use of linking phrases between concepts. Novak and Gowin (2016) stated that a linking phrase should join concepts to form a meaningful proposition, which is a basic unit of knowledge according to the theory of meaningful learning and Ausubel's Assimilation Theory. Concept mapping theory does not constrain the labels that can be used, allowing map makers more freedom and precision in describing the relationships among concepts. Researchers using other types of graphing methods have prescribed a limited number of linking phrases that, they claim, can be used universally.

2.9.4 Definition of nodes

All the graphing systems we have mentioned make some distinction between nodes and links. In Novak and Gowin's (2016) seminal work on Concept Mapping, a concept is defined as a ―perceived regularity in objects or events". Though one must accommodate the fact that concepts can denote things that cannot be perceived (e.g., unicorns), this remains a good working definition. Typically, a concept is expressed using one or just a few words, one of which is a noun or gerund. Other graphing systems maintain this definition of concept (e.g., Fisher, 1990; Herl, O'Neil, Chung & Schachter, 1999; O'Neil, 1999). However, the Mind Mapping methodology (Buzan & Buzan, 1996) allows for concepts (or nodes) that can be images, thoughts, ideas, or sentences. In Cognitive Mapping (Ackerman & Eden, 2001; Eden & Ackerman, 2001), the nodes are regarded as ―ideas," which can be sentences or paragraphs. Limiting node contents to concepts allows for a more explicit representation of the interrelationships among concepts, and is a defining characteristic of the notion of Concept Maps.

2.10 An Illustration of Concept Map

This section is made up of a Concept Map that illustrates their defining characteristics. The concepts in this Concept Map are surrounded by boxes, and the Linking Phrases reside on the directed arcs between the concepts. The linking lines are all labelled with Linking Phrases that make explicit the relationships among the concepts. The concepts are single words or short phrases rather than sentences or paragraphs. The Concept Map contains many concepts that are richly interconnected.

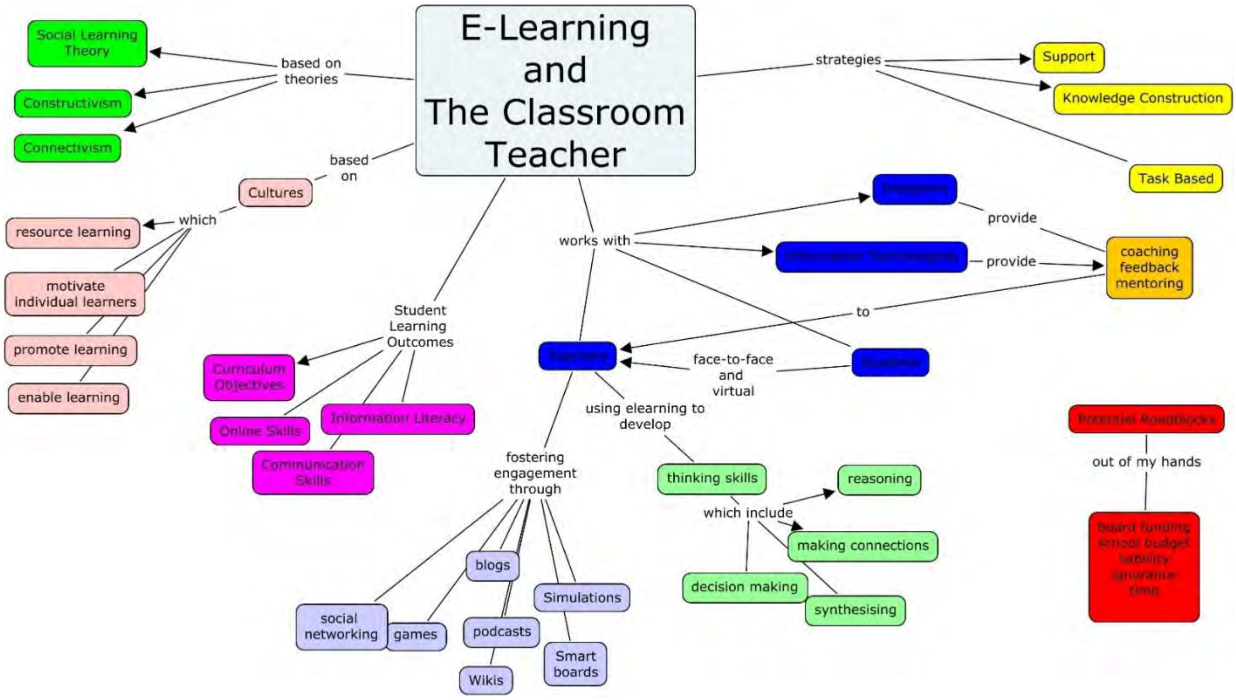

Figure 4: A Concept Map Pertaining E-Learning (Schwendimann, 2015).

The Concept Map has a basic ordering of the concepts from general to specific from the top to the bottom, illustrating the notion of subsumption by Ausubel (2000). At the top of the Concept Map, the most general, superordinate concept, ―E-Learning and the Classroom Teacher” is observed. Just below that are several concepts. Further down in the map are more detailed concepts.

2.11 Construction Methods for Concept Maps

Concept Maps can be constructed by using a variety of methods. The method that is employed depends on the purpose of map construction. Concept Maps can be constructed either by hand or with the assistance of software that supports specific tasks or general diagramming. Concept Maps can be constructed by individuals or groups, either with or without facilitation.

2.11.1 A standard concept map construction method

The Concept Mapping method defined by Novak and Gowin (2014) involves a series of steps.

- Define the topic or focus question. Concept Maps that attempt to cover more than one question may become difficult to manage and read.
- Once the key topic has been defined, the next step is to identify and list the most important or ―general" concepts that are associated with that topic.
- Next, those concepts are ordered top to bottom in the mapping field, going from most general and inclusive to the most specific, an action that fosters the explicit representation of subsumption relationships (i.e., a hierarchical arrangement or morphology).
- Once the key concepts have been identified and ordered, links are added to form a preliminary Concept Map.
- Linking phrases are added to describe the relationships among concepts.
- Once the preliminary Concept Map has been built, a next step is to look for crosslinks, which link together concepts that are in different areas or sub-domains on the map. Cross-links help to elaborate how concepts are interrelated.
- Finally, the map is reviewed and any necessary changes to structure or content are made.

Figure 5 presents a Concept Map that illustrates several points regarding Concept Map construction. It is a Concept Map that is in-progress. It started by identifying and entering many of the important concepts that they wanted to consider. Some of the concepts have been linked together by linking phrases. The concepts in the lower right portion that are not yet linked into other concepts are part of what we call the ―parking lot” where concepts for which relationships haven't been established are located. The students creating this Concept Map are on step 4 from the previous list. They have defined a question, ―What is Solar Radiation?” They have identified and entered the basic concepts, distributed them from general to specific, and started linking them together.

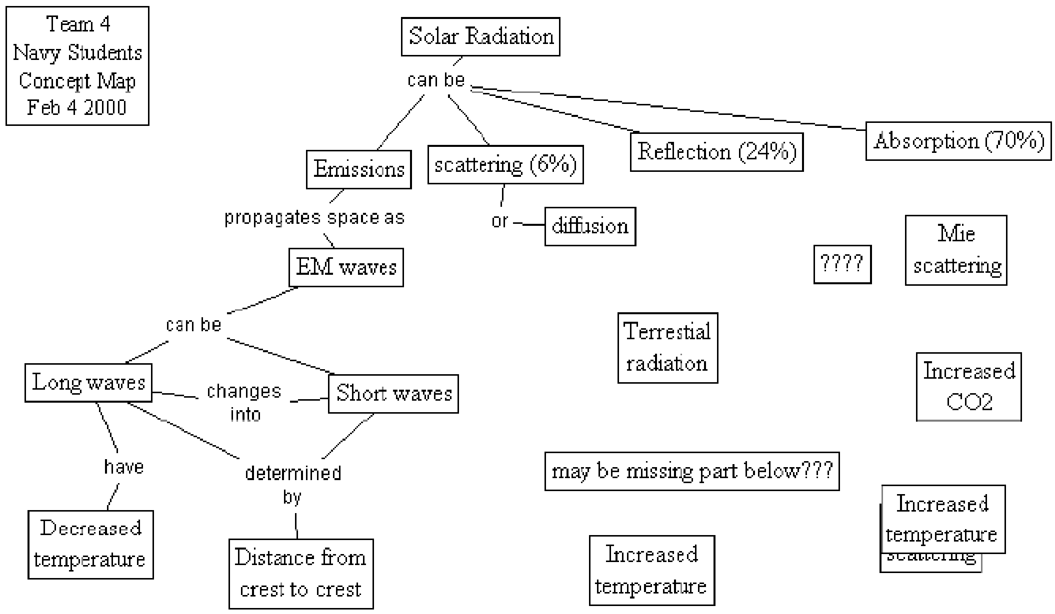

Figure 5: A Concept Map on Solar Radiation (Schwendimann, 2015)

Figure 6 contains the final version of the Concept Map from Figure 5. Students have completed the process of identifying concepts, adding several more to the previous map. They have linked the concepts together, and identified cross-links. This map displays a good vocabulary of concepts for novice Aerographers, and a well-integrated set of linking phrases. The long, sweeping links among ―Greenhouse effect”, ―Short waves,” and ―Absorption,” illustrate the cross-links. Although the labelling of the cross-links could be improved, the fact that they are there at all indicates that the students had some sense that a relationship exists among these rather disparate concepts. Concept Mapping facilitates the learning process by allowing the instructor to identify missing or irrelevant concepts, trivial or incorrect linking phrases, etc. The Concept Map provides the basis for discussions between students and their instructors, to clarify relationships such as the one depicted, and generally to gain a better understanding of the subject matter.

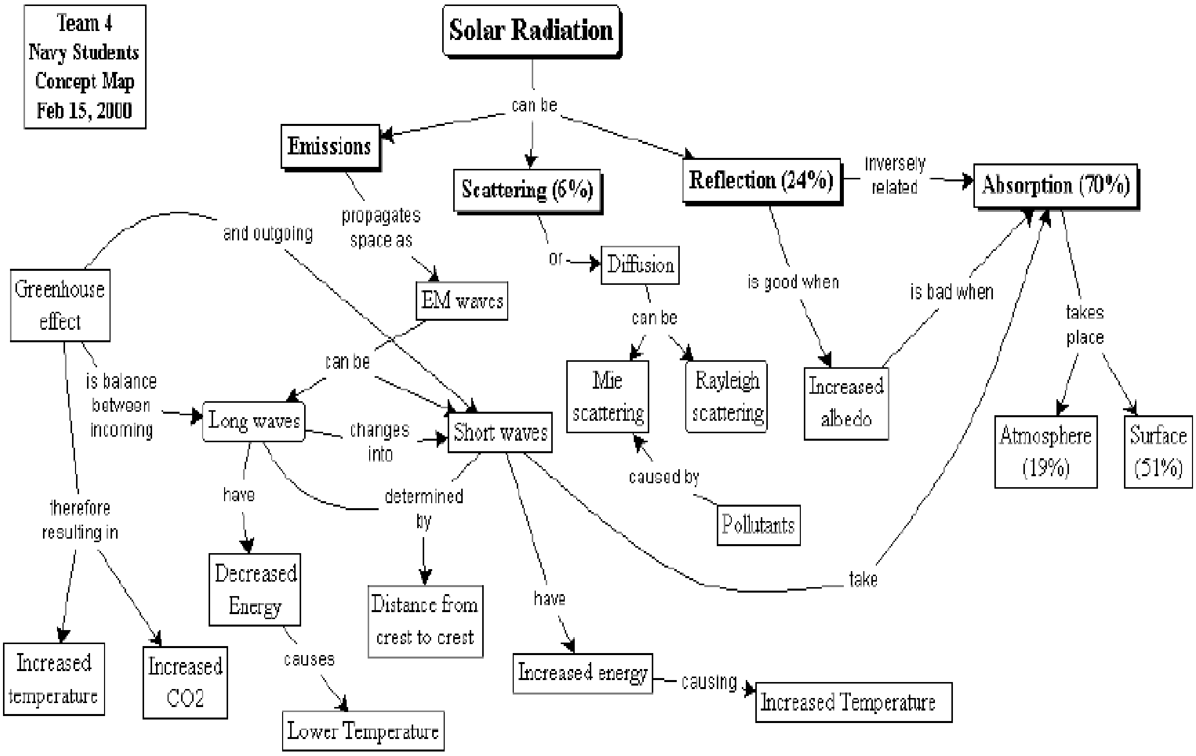

Figure 6: Final Concept Map on Solar Radiation (Schwendimann, 2015).

It should be noted that the process described here contains descriptions of the activities that typically occur in a successful Concept Mapping effort. It is rare that the actual process unfolds in such a clearly proscribed, sequential fashion. Often, Concept Map creators simply jump right in, creating concepts and linking them together. As in the conduct of most processes, more initial thought and overall systematic arrangements foster better results. The next sections describe other methods of Concept Map construction.

2.11.2 Variations on the standard map construction method

A characteristic of the standard method of Concept Map construction described above is that the only constraints are the structural format of the map (subsumption expressed in a semi-hierarchy), and the limits imposed by using appropriate concepts and linking words. This method is preferred because it allows the creator freedom in the representation of knowledge. Other methods of map construction have been used to serve a variety of goals, including ease of computer implementation, ease of construction by students and so forth. Researchers have described and compared several Concept Mapping techniques (Ruiz-Primo & Shavelson, 2006). who suggested that the degree of control or directedness in map construction differs in different mapping tasks. Map builders can be given the structure of the Knowledge Map, and lists of concepts and linking words to use to fill in the slots in the graph (a fill-in task). At the opposite extreme, the creator may be required to provide all concepts and linking phrases (a graph-from-scratch task). Aside from encouraging the semi-hierarchical format, the method proposed by Novak and Gowin (2014) is a low-directedness mapping task. Ruiz-Primo and Shavelson (2006) have suggested that graph construction tasks that are low in directedness may provide clearer insights into differences among students' knowledge structures.

Other Concept Mapping methods include variations designed to address specific tasks or settings. For example, Concept Maps can be constructed based on interviews with students, experts, or other individuals. Concept Maps can be constructed by individuals or by collaborative groups, either in the same location or in remote locations, facilitated by computer networks. Concept Maps can be constructed with or without the use of a facilitator, either within a group or an individual setting. In either case, the facilitator may simply play the role of transcriptionist, or may actively promote elaboration or clarification of ideas in the Concept Map, and improvement of map structure. Concept mapping software has been designed to provide different types of facilitation for map construction, including online scoring and assessment of maps, or suggestions about improvements that may be made to the Concept Map.

2.12 Collaboration in the Construction of Concept Maps

Although the standard method of Concept Mapping presumes that a Concept Map can be made to represent an individual's current level of knowledge and understanding, in many cases Concept Maps can be constructed as part of a collaborative group process. Concept Mapping can facilitate the exchange of information in a group, can make the viewpoints of individual collaborators clearer, and can encourage participation in the collaborative process. In educational settings, collaborative Concept Maps have been used for group projects, and have been compared to other types of group projects such as posters (Van Boxtel, Van der Linden & Kanselaar, 1997; 2000). In business settings, Concept Maps have been used to facilitate discussions among different groups within a company. Creation of collaborative Concept Maps by experts has been used to preserve organizational knowledge (Huff & Jenkins, 2002; Johnson & Johnson, 2002). Other types of graphing methods have been used in business for the purpose of problem solving and project management. Collaborative creation of Concept Map may take many forms. Sessions may be conducted face-to-face or at a distance, and may be synchronous (all participants working concurrently) or asynchronous (e.g.: one collaborator completes edits and then another collaborator edits). Collaborations in the construction of Concept Maps in any of the contexts described in the previous paragraph can be performed locally or at a distance and synchronously or asynchronously. As in the case of individual map construction, a well-defined focus question must be formulated. One method of collaborative

Concept Map construction entails group identification of concepts and their relationships. One means of improving efficiency in group Concept Map creation is by the identification of a group moderator and a recorder or ―driver" who records the concepts and builds the Concept Map. Negotiation and compromise must take place in the group construction of a Concept Map. It should be noted that participants might have irreconcilably different opinions that are made evident by the process. Such differences can cause the mapping process to stall. In such cases, it is probably best to separate out the conflicting ideas into two Concept Maps, and continue in separate groups. An attempt to reconcile differences can be made when both positions are clearly mapped.

Another form of collaboration in Concept Map construction is allowing the user access to related maps in development by others. There are multiple ways to provide this capability, including searching for related maps on public servers and collaboration capabilities provided by a software system. Cañas, Hill, Granados, Pérez and Pérez (2003) describe the extensive networking provided by the CmapTools software in support of synchronous and asynchronous collaboration and sharing during Concept Map construction. A different form of collaboration is proposed by Cañas *et al*. (2001), whereby a Knowledge Soup stored in a shared server allows students from distant schools to share claims (propositions) derived from their concept maps regarding any domain of knowledge being studied. The literature also contains descriptions of the use of collaborative Concept Mapping in business settings (Novak, 2008; Fraser & Novak, 1998). Other group graphing methods and problem-solving techniques have been used in business settings. For instance, the collaborative use of Decision Explorer ―Cognitive Maps" (Ackerman & Eden, 2001; Eden & Ackerman, 2001), ―Quest Maps," (Conklin, 2002a; Conklin, 2002b; Conklin *et al.*,

2002) and ―Mind Maps" (Buzan & Buzan, 1996), suggests a growing interest in collaborative mapping techniques in business. However, our ability to describe the use of Concept Maps in business has been limited by the availability of literature pertaining to such uses, since confidentiality issues are significant in business settings.

2.13 Facilitation of Concept Map Construction: Human Facilitators and Computer Support

Facilitation in the creation of Concept Maps can take several forms. A distinction can be made between assistance provided by human facilitators and assistance provided by computer software to construct Concept Maps (Conklin, 2002b). The nature of the facilitation depends on the goals of the mapping effort. If the goal is to use Concept Mapping in an educational setting to help students learn meaningfully, or for the assessment of structural knowledge, then the facilitator is essentially a teacher who must help the student learn how to make Concept Maps. Guiding students through the steps in the standard method described earlier and presenting examples of good Concept Maps are effective strategies to pursue this end (Conklin, 2002b). If Concept Mapping is being used as a vehicle for knowledge elicitation, the facilitator plays a different role. In this case, the expertise resides within the expert, and the facilitator's role is to help create, or co-create with the expert, an explicit representation of that knowledge in a Concept Map. A facilitator in this setting may perform several functions including that of a knowledge elicitor, an interviewer who simultaneously creates a Concept Map reflecting the ideas that emerge from the interview, a ―cheer leader" who encourages an effort to achieve clarity, consistency, and completeness, and even a monitor to encourage all the various group members to become involved in the mapping process. When group Concept Mapping is being performed, it is desirable to allow the emerging Concept Map to be viewed by all participants by using computer software and a projector, or by creating a representation on a whiteboard. Any of the group members can facilitate insofar as they contribute to the attempt to refine the Concept Map. The role of a designated facilitator is to assist in the elicitation of knowledge and ideas from group members, and to assist in construction of a Concept Map representation that adequately represents the necessary information in a well-designed and readable Concept Map.

Another type of support might come from the software itself. Ideally, electronic facilitation might provide an individual with information about good Concept Mapping form and process (e.g., hierarchical structure in maps, the definition of focus questions, adequate distinction between concepts (nodes) and linking phrases, clear specification of linking phrases and so forth). Although this level of support may seem to be relatively basic, providing such feedback is a very difficult task to automate. Tools may also provide differing amounts of support for users in terms of predefined concepts and links. As discussed earlier, the standard Concept Mapping procedure does not specify a set of linking phrases (though examples may be offered), to allow for the most comprehensive expression of knowledge. However, in many educational settings graphing and assessment procedures have led to the development of constrained map authoring systems, in which the concepts and linking phrases can be pre-defined based on expert analysis of the domain before student mapping (Chung *et al*., 2002). The graph construction process allows users to choose the concepts and linking phrases which is a limited form of facilitation. In addition, Concept Map systems might provide online access to WordNet, the Web or other related information directories, which may provide access to concepts and relationships that could or should be incorporated within a given Concept Map on a given topic. Cristea and Okamoto (2001) describe a course authoring system in which manual linking of course topics in a Concept Map can be aided by automatic linking of topics based on keywords defined in the course material. The instructor or course designer is then asked to verify these connections.

2.14 Educational Importance of Concept Maps

Information is processed and stored in the mind of children in linguistic, visual and in a complex set of interrelated memory systems. All incoming information is organized and processed in the working memory by interaction with knowledge in long-term memory (Birbili & Lin, 2001). Although the structure must be built up piece by piece with small units of interacting concept and propositional frameworks, CM serves as a kind of template or scaffold to help organize knowledge and structure it. Once children learn how to read and make CM, it is easy for teachers to identify their prior knowledge as well as misconception and use it as an assessment tool (Birbili & Lin, 2001; Cook, 2017).

2.15 Concept Teaching and Learning

Concepts in any subject are the basic building blocks for higher-level thinking. Without understanding concepts, there is no comprehension and cognitive development. They are bodies of knowledge or the mental representation that people have about entities in the world that stored in their memory and used in the process related to higher capacities (Kokkonen, 2017). In teaching and learning of any science subject, concepts do not exist in isolation instead interrelate for meaning (Stoica *et al*., 2011). However, many students have difficulties in identifying the main concept of the topics in text, lecture, and other forms of presentation. The problem comes from the methods of learning that simply required memorization of information but not required evaluation. Such students fail to understand concepts and leading them to conceive learning as a blur of myriad facts or procedural rules to be memorized (Jibrin & Zayum, 2012). For such students the subject matter of most disciplines is a cacophony of information to memorize, and they usually find this boring. CM has been explored as learning tool in a wide range of science disciplines including chemistry, biology, physics, earth science, ecology, astronomy, and medicine (Schwendimann, 2015). Instructional CMs are flexible tools that can be used in a variety of educational settings including knowledge construction, meaningful learning, assessment evaluation of students understanding and misconceptions, and instructional planning (Adlaon, 2012).

2.16 Instructional Concept Maps (ICM)

The technique of representing knowledge consists of network of concepts which include nodes and links. The nodes are the concepts which are connected through links (words) to form meaning of propositions (statements). The concepts are usually enclosed in circle or box and relationships between concepts or propositions, indicated by a connecting line between two concepts. The propositions contain two or more concepts connected with other words to form a meaningful statement (Jacobs-Lawson & Hershey, 2002). Concept mapping shows the key concepts and propositions in explicit and concise words and the superordinate-subordinate relationship between key concepts and propositions in graphs. Therefore, CM provides better idea about how to sequence learning materials for presentation (Galvin *et al*., 2015). It has an implication on students to acquire cognitive understanding of knowledge of subjects and concepts, and a mastery of the skills for their private studies in science (Kinchin, 2001).

The results from a quasi-experimental study conducted by Birbili and Lin (2001) on investigating the effectiveness of CM instructional method on students' performance and understanding of science subjects including biology, physics and chemistry at early childhood education indicated, students who were exposed to CM instructional methods have better performance and understanding of the lessons than those exposed to traditional instructional methods. Similarly, Cheema and Mirza (2013) conducted an empirical study on the effect of CM instructional method on academic achievement of grade 7th students in general science subjects in Sargodha city. Based on the achievement test developed by these researchers' students who were taught with CM instructional method have better performance in the achievement test than those who were taught with a traditional method. CM instructional method is also effective to apply on slow learners. A quasi-experimental study conducted by Udeani and Okafor (2012) on secondary school biology slow learner students at Enugu State in south eastern Nigeria indicate that these students perform better when they are taught with CM instructional methods than traditional instructional method on photosynthesis.

However, Adlaon (2012) observed that students who were taught with CM method did not score significantly than those who taught with traditional teaching method at the post-test result on the concept of balancing nature in high school biology. As this researcher described in his study, the possible reasons for this were students' frustrations in CM activities, less involvement of students in CM activities and teacher constructed CM rather than student-based in the learning progress.

2.17 Applications of Concept Maps in Educational Settings

Plotnick (1997) observed uses of Concept Maps in education and suggested potential uses of Concept Mapping in education, advantages of Concept Mapping (mostly based on visual representation), and advantages of computer support for Concept Mapping. These included the dynamic nature of linking, conversion of Concept Maps to other formats, and electronic storage. Uses of Concept Mapping as stated by Plotnick (1997) include creativity, hypertext design (or design of other complex structures), learning, assessment, brainstorming, communication of complex ideas, and so forth. White and Gunstone (1992) described uses of Concept Maps in education that are primarily based on assessment of changes in learner's understanding. These uses might include assessment of understanding of a limited aspect of a topic, assessment of whether learners can make links among concepts and the changes that occur in these links, assessment of whether learners understand goals of instruction, identification of which concepts are perceived as key concepts by learners, and promotion of collaboration among learners. Other overviews of educational applications of Concept Mapping include Pankratius and Keith (2007) and Novak and Gowin (2014).

3.18 Uses of Concept Maps as a Tool to Support Learning

Concept Maps created by students can be used in several ways to facilitate meaningful learning. Novak and Gowin (2014) pointed out that Concept Maps are a kind of schematic summary of what students know. They can be used to display students' prior knowledge about a given topic, or they can be used to summarize what has been learned, for example, after reading an assignment or completing some other classroom lesson. In this regard, Concept Mapping is often used for note taking or as a study aid. Novak and Gowin (2014) noted that the act of mapping is a creative activity, in which the learner must exert effort to clarify meanings, by identifying important concepts, relationships, and structure within a specified domain of knowledge. The activity fosters reflection on one's knowledge and understanding, providing a kind of feedback that helps students monitor their learning and, perhaps with assistance of teachers or peers, focus attention on learning needs. As a creative activity, Concept Mapping can also be used as a planning tool or as an alternative to essay writing.

From the volume of literature about uses of Concept Maps, it is easy to conclude that the most prevalent use of Concept Mapping is for teaching and learning. Many studies have shown that mapping yields benefits for learning although some have not (Horton *et al*., 2017). Following are some illustrations of the ways of using Concept Maps that have been shown to enhance learning and discuss briefly the kinds of students that mapping seems to help most;

- as a scaffold for understanding,
- for consolidation of educational experiences,
- to improve affective conditions for learning,
- as an aid or alternative to traditional writing,
- to teach critical thinking, and
- as a mediating representation.

2.18.1 Identifying current understanding, misconceptions, conceptual change

What conceptual understandings students achieve in a new learning activity is highly dependent on what they already know. Concept Maps have been used to examine students' prior knowledge, to track a student's progression of knowledge throughout a course, to compare students at different levels of knowledge and so forth (Adamczyck & Willson, 1996; Hoz, Bowman & Kozminsky, 2001; Pearsall, Skipper & Mintzes, 1997; Troncoso, Lavalle, Curia, Daniele & Chrobak, 1998). Concept Maps have also been used to identify specific misconceptions in knowledge (Gonzalez, 2017; Regis & Albertazzi, 2016; Trowbridge & Wandersee, 2014), and to identify alternative educational approaches to address misconceptions (Kinchin, 2001; McNaught & Kennedy, 2017; Passmore, 2018). Teachers and students are often able to identify misconceptions more clearly within the context of a Concept Map. Lavoie (2017) found that using a reflective writing exercise in conjunction with Concept Mapping revealed additional misconceptions and provided more information about students' understanding than did mapping alone. Kinchin, Hay, and Adams (2018) proposed that qualitative assessment of students' Concept Maps is more appropriate than quantitative methods when the intent is formative assessment of student learning. Edmondson and Smith (2016) used Concept Maps in several different ways in a veterinarian curriculum.

Faculty members were able to identify student misconceptions and adjust teaching to address these. Abd-El-Khalick and BouJaoude (2007) used Concept Maps in conjunction with questionnaires and interviews to study in-service teachers' understanding of the structure, function, and development of their respective science disciplines. Beyerbach and Smith (2015) tracked pre-service teachers' knowledge about the processes of teaching and learning, using Concept Maps teachers constructed throughout their final year of the teacher preparation program. Ferry, Hedberg and Harper (2008) suggested that Concept Mapping helps pre-service teachers to organize their knowledge and curriculum content in integrated frameworks. Jones, Carter and Rua (2019) used teachers' pre- and post-course Concept Maps, along with journal reflections and portfolios, to examine professional growth as a result of changes in conceptual understanding of content and pedagogical knowledge. In contrast, Lang and Olson (2000) and Winitzky and Kauchak (1995) looked at preservice teacher knowledge and the effects of practical experience, found decreases in complexity and organization of knowledge from pre-or early course to post-course Concept Maps. Finally, Morine-Dershimer (1993) used pre- and post-course Concept Mapping to assess conceptual change in pre-service teachers. She developed a scoring technique that enabled her to identify patterns of change associated with features of the educational environment, which, she suggested would be useful for course or program evaluation.

2.19 Assessment of Learning Using Concept Maps

Concept Maps can be used in formative or summative assessment procedures. In formative assessment, learners may be asked to make Concept Maps at various points in the learning process, and teachers can use these maps both to assess the learners understanding and to modify the curriculum. Summative assessment can be used at the end of an instructional unit to determine a learner's understanding of that unit, and to assign grades.

2.19.1 The utility of concept maps for assessment

Concept Maps constructed as ongoing evaluation of knowledge within a course, or across instruction in a discipline can be useful in demonstrating the changes that occur in a student's knowledge structure and the increasing complexity of knowledge structure that develops as students integrate new knowledge with existing knowledge. For example, Wallace and Mintzes (2013), described the use of Concept Maps to demonstrate conceptual change. After instruction, all participants took a post-test, which included the same objective test taken as a pre-test and the construction of a Concept Map based on marine life zones. Results indicated that the experimental group showed small increases after instruction on the objective test. Other work on the utility of concept maps for assessment is presented in Markham and Mintzes (2004), Pearsall, Skipper and Mintzes (1997), and Martin, Mintzes and Clavijo (2000).

2.20 Evidence of Effectiveness of Concept Mapping for Education

Concept Mapping had its roots in education, and education and learning probably still constitute the bulk of its use. Hence, the purpose of this section is to review a few studies of the effectiveness of Concept Mapping as a learning tool. The issue is not whether Concept Mapping enhances learning. Like any other tool, the effectiveness of Concept Mapping depends on how it is used and the conditions in which it is used. There is no doubt that Concept Mapping can enhance learning. An earlier study of the educational effectiveness of Concept Mapping (Horton *et al*., 2017) concluded that Concept Mapping can have educational benefits that range from what can only be described as huge, all the way to having negative effects (i.e., when some alternative instructional intervention produced learning effects greater than Concept Mapping), although the great majority of the studies reviewed showed differing degrees of positive effect for Concept Mapping. This section will contain a brief overview of the fourteen studies examined.

2.20.1 Studies with random assignment of learners to conditions

The purpose of a study by Esiobu and Soyibo (1995) was to test effects of Concept Mapping and Vee diagramming in different forms of instruction. The study took place in Nigeria and involved secondary school students. The subject matter was ecology and genetics. The results were that students in the treatment conditions greatly outscored those in the controls in all learning conditions. This is one of the strongest demonstrations of the educational effectiveness of Concept Mapping to be found. Schmid and Telaro (2017) sought to test the effectiveness of Concept Mapping on high school biology achievement and to assess this by student academic ability level. The study was conducted in Montreal, Canada and involved students at levels –4 and 5” of the Canadian system. The subject matter was a unit of a biology course on the nervous system. The experimental design combined treatment and control crossed with three levels of Academic Ability (high, medium, and low). The results indicated that the helpfulness of Concept Mapping increased as groups went from high to medium to low ability. The authors speculate that Concept Mapping helps low ability students to a greater degree because it requires them to take an organized and deliberative approach to learning, which higher ability students likely do anyway.

The goal of a study by Bascones and Novak (2018) was to test the effect of Concept Mapping on students’ problem solving in physics. The teaching process used in this study was based on Ausubel’s (1963) theory of meaningful learning. The course was a required physics course taught throughout Venezuela. The design involved two groups. The treatment group had general-to-specific orderings of content and routine Concept Mapping exercises, while the control group had traditional instructional methods. The results showed large effects in favour of the treatment group on every test administration and at all ability levels. The results of this study clearly present a strong statement for the benefit of the instruction that was based on Ausubel’s (1963) learning theory and some sort of utilization of Concept Maps.

2.20.2 Studies in which classes were randomly assigned to conditions

Pankratius and Keith (2007) sought to test if Concept Mapping, and especially the amount of Concept Mapping, would affect achievement in physics problem solving.

The main variable was the amount of Concept Mapping practice/experience the students were engaged in. One treatment group created Concept maps at the beginning of a unit and continuing to improve them throughout, a second treatment group made Concept Maps once at the end of a unit. A control group did not make Concept Maps. The results showed statistically significant differences, with both treatments performing better than the control, and periodic Concept Mapping being more effective than Concept Mapping just at the end of the unit. A study by Czerniak and Haney (2008) was designed to test if the addition of Concept Mapping to instruction in a physical science course would improve achievement, reduce anxiety toward physical science, and reduce anxiety about teaching physical science at the elementary school level. The results showed that Concept Mapping increased achievement, decreased anxiety for learning physical science, and decreased general (trait) anxiety. Results did not indicate an increase self-efficacy for teaching physical science. The goal of Jegede, Alaiyemola and Okebukola (2020) was to test whether the addition of Concept Mapping to instruction would aid achievement and reduce anxiety (toward biology subject matter). The study was conducted in Nigeria, with students who were the American-equivalent of grade ten. The results were dramatically in favour of Concept Mapping. There were positive effects in favour of the Concept Mappers in both achievement and for anxiety reduction.

2.20.3 An alternative educational intervention compared to concept mapping

A study by Spaulding (2019) addressed the effects of Concept Mapping versus ―concept defining" on learning achievement in biology and chemistry. The results showed no differences between Concept Mappers and Definers. There was also no differential effect for chemistry vs. biology. The statistical interactions indicated that lower ability students performed better with Concept Mapping, and higher ability students performed better when just defining the concepts. In another study that found no treatment effect, Lehman, Carter and Kahle (2015) tested the effects of Concept Mapping (with Vee diagramming) vs. ―outlining" on improving achievement in a biology course. No statistically significant differences were found in the study. Zittle (2012) set out to determine the relative effectiveness in producing analogical transfer of studying text, studying a completed Concept Map, or filling in a blank, but structured Concept Map. The study involved three groups: one that studied text; a second that studied Concept Maps; and a third that selected concepts to fill in Concept Maps. The dependent variable was the number of hints required for solving a set of problems. The text and Concept Map groups were nearly identical (requiring 7.3 vs. 6.2 hints respectively). The group that filled in the Concept Maps required only half as many hints (3.4). A study by Chang, Sung and Chen (2011) sought to test the benefits for learning of three different kinds of uses of Concept Maps. The design involved four conditions, one control and three experimental, and a pre- and post-test.

Twice per week for four weeks, students read one of the science articles and studied it under one of the four conditions. In the Map Generation group, students constructed a Concept Map for the material from scratch. In the Map Correction group, students were given an ―expert-generated" Concept Map for the material, in which some errors had been introduced. Students were to find and correct these errors. In the Scaffold-Fading group, students were progressively weaned from pre-constructed Concept Maps. The control group received no adjuncts at all, just the original text to read and study. The results showed that ―the map-correction group did better on the (comprehension) post-test than the map-generation and control did, and the differences among the scaffold-fading, map-generation, and control group were not significant" (p 15).

2.20.4 Studies that compared concept maps with other forms of learning material

The goal of Hall and O'Donnell (2016) assessed free recall memory of material presented as either text or as a Knowledge Map. The results were that the Knowledge Mapping group showed better recall for both superordinate and subordinate materials. Rewey *et al*. (2019) tested the effects on learning of the format of supplemental materials, i.e., “knowledge mapping” vs. text. vs. no supplement, across three styles of instruction: cooperative learning vs. cooperative teaching vs. individual study. Two major results were that the Knowledge Mapping groups did not outperform the other supplement groups, although trends in that direction were apparent. Neither did the cooperative groups outperform the students who worked alone.

2.21 Empirical Review

More than two hundred studies in science education have employed concept mapping in one form or another (Novak, 2008; Mintzes, Wandersee & Novak, 2015). Several of these investigations have examined the reliability and validity of the technique as a way of representing knowledge in scientific disciplines (Markham, Mintzes & Jones, 2004; Ruiz-Primo & Shavelson, 2006). For example, in one study (Markham *et al*., 2004) it was shown that the conceptual frameworks revealed by concept maps reflect essentially the same structure as that seen in much more time-consuming techniques, such as interviews and picture sorting tasks.

The effectiveness of concept mapping has also been compared to several other learning techniques. For example, learners who used concept mapping as a learning strategy performed better than learners who used underlining (Amer, 2004), note-taking (Reader & Hammond, 2005), or outlining (Robinson & Kiewra, 2015). There has also been some research on worked out concept maps. These are maps that have been constructed by a teacher or an expert and provided to students as a learning tool. Students with low verbal abilities have been shown to benefit from studying such worked-out maps (O'Donnell, 2002; Rewey *et al*., 2008). In addition, learners with low prior knowledge of the content domain also profit from learning from worked-out concept maps (Lambiotte & Dancereau, 2012). The following paragraphs report past studies designed to improve science achievement by using concept maps for knowledge construction, learning and assessment.

The goal of a study by Bascones and Novak (2018) was to test the effect of Concept Mapping on students' problem solving in biology. The teaching process used in the study was based on Ausubel's (1963) theory of meaningful learning. The design involved two groups. The treatment group had general-to-specific orderings of content and routine Concept Mapping exercises, while the control group had traditional instructional methods. The results showed large effects in favour of the treatment group on every test administration and at all ability levels. The results of this study clearly present a strong statement for the benefit of the instruction that was based on Ausubel's (1963) learning theory and some sort of utilization of Concept Maps. Schmid and Telaro (2017) assessed the concept mapping as an instructional strategy to use with high school students in learning Biology concepts. The concept mapping technique was compared with an established curriculum approach and tested in an interaction with learners of varying ability. The sample was drawn from students who had chosen Biology as an optional course at Montreal high school in Canada. The procedure involved administering SDRT to rank the students according to reading ability. The first instructional strategy was a traditional approach where the classroom teacher covered the Nervous system content and where the main method was lecturing, using teacher- and professionally prepared materials. The second approach was concept mapping technique. The results also showed that there were significant differences between the high-reading-ability experimental and control groups and between the low- ability control group and the high ability control group. Individual comparisons of means indicated that the low-reading-ability concept mapping students performed significantly better statistically than did the low-ability control group. The students with high and medium ability showed no differences. It showed that concept mapping facilitated low ability learners' performance, but only higher level, relational knowledge. The usefulness of the strategy was discussed in terms of its ability to individualize and raise the quality of learning with little extra effort or resource costs to the instructional system. The effectiveness of concept maps as advance organizer in improving achievement of students in science was also assessed by Willerman and MacHarg (2019) on 82 eighth-grade students in four physical science classes at a middle school in a North Chicago suburb with an experimental group that had 40 students and a control group that had 42 students.

The experimental group completed the concept map at the beginning of the science unit under the teacher's supervision while the control group was given an introductory lesson with questions. At the end of the two- week unit a science test was administered to the experimental and the control group. The results of a one-tailed t test indicated that there was a significant difference between the two groups with effect size of 0.40, which is well within the range of other advance-organizer studies. The study confirmed the hypothesis that students who are presented with a concept map that is used as an advance organizer at the beginning of a physical science unit will score higher on a unit test than students who are not presented with the concept map. Several studies suggest that concept map scores do not correlate significantly with traditional measures of learning such as multiple-choice tests. Novak, Gowin and

Johansen (2016) showed that mapping scores were not significantly related to students' SAT scores. These findings suggest that a concept map taps into a substantially different dimension of learning than conventional classroom assessment techniques. It is likely that many techniques commonly used in college science courses focus largely on rote aspects of learning. On the other hand, Schau *et al.* (2015) found that post-test scores on maps drawn by graduate students in introductory statistics correlated significantly with final course grades. The interpretation from this study is that traditional evaluation tools (quizzes, tests, final grades) capture some aspects of conceptual structure, and concept maps capture other aspects.

2.22 Theoretical Framework

The learning theory underpinning this study is the assimilation learning theory by Ausubel (1963). Ausubel (2000) stated that ―If I had to reduce all educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly." According to Ausubel et al. (1978) what a learner already knows refers to the concepts and propositions that have meaning to the learner.

2.22.1 The Essential Principles of Ausubel's Theory

Ausubel's theory has six basic principles: The first two principles are rote learning, which occurs when the learner makes little or no effort to relate new knowledge to relevant elements of knowledge the learner already knows, whereas meaningful leaning occurs when the learner makes a deliberate, conscious effort to relate new concepts and propositions to existing, relevant concepts and propositions. Only the learner can choose to learn meaningfully, although there are strategies that can encourage this kind of learning. Ausubel (1963) argued that rote learning and meaningful learning are two different, distinct ways of learning. He maintained that the quality and extent of meaningful learning depended both on how much effort and commitment the learner makes to relate new learning to her/his existing knowledge and on the quality and degree of organization of that existing relevant knowledge. Therefore, cognitive learning should be viewed as a continuum, arbitrary acquisition of information to very high levels of meaningful learning. More recently, Novak (2010) argued that creativity could be viewed as essentially very high levels of meaningful learning. This view is expressed in Figure 7.

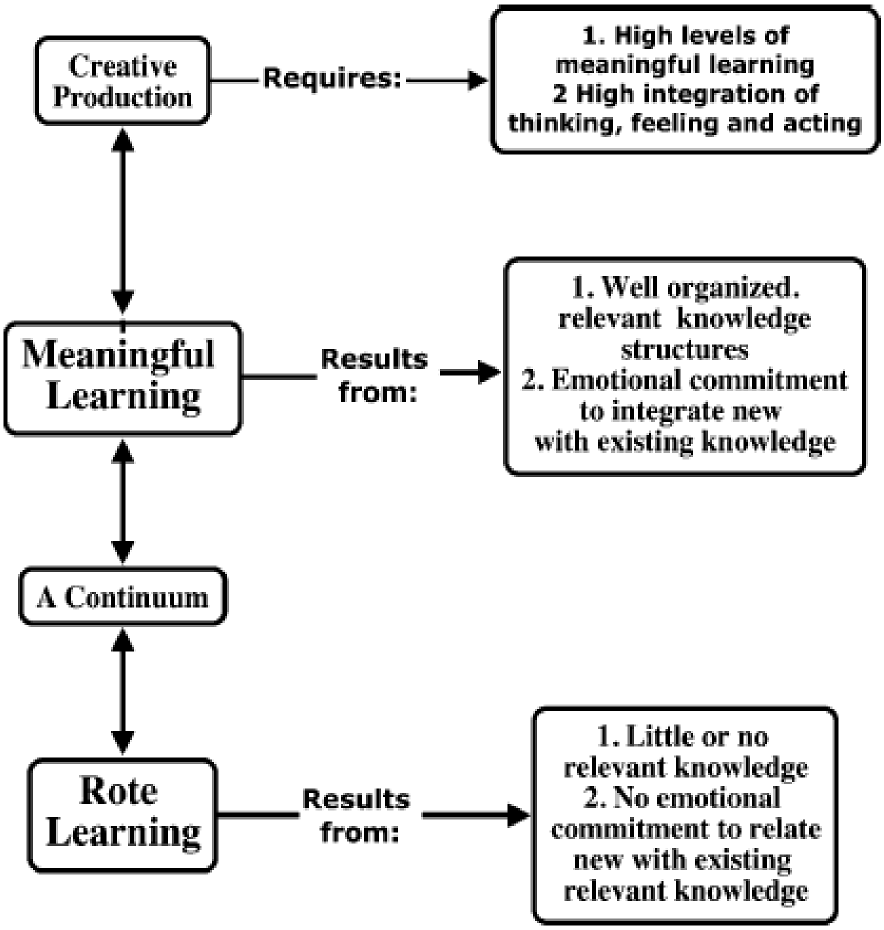

Figure 7: The Rote-Meaningful Learning Continuum (Novak 2010)

The third key principle of Ausubel's (1963) theory is subsumption. When new concepts and propositions are incorporated into relevant, more general concepts and propositions, subsumption occurs and both the existing superordinate knowledge and the newly incorporated idea are modified. Ausubel (1963) maintained that subsumption is the most common form of meaningful learning. This view has been supported by research conducted by Novak (2010). In extreme rote learning, the process of subsumption does not occur where one can think of the new bits of knowledge as just kind of floating around in cognitive space, each in isolation of all other elements. There are two negative results from this kind of rote learning. First, there is no enhancement and refining of meanings for existing concepts and propositions. Consequently, these existing ideas do not (and cannot) become more powerful subsuming concepts nor more differentiated ideas that can serve better for problem solving or creative work. Second, faulty ideas or misconceptions held by the learner do not get corrected or altered into more accurate forms. Research has shown that students who learn primarily by rote are poor at solving novel problems and they do not modify and correct their faulty conceptions; nor do they consider in any way relevant alterative conceptions they use to interpret their world (Novak, 2010).

The fourth principle in Ausubel's (1963) theory is obliterate subsumption. This occurs when over a span of time, discrete ideas are subsumed into more general concepts and later can no longer be recalled as discrete ideas (hence ―obliterate"). These concepts and propositions have contributed to elaborating the more general idea into which they were subsumed, but we can no longer recall them independently. All of us have experienced occasions when we knew that object or event belongs to a certain category of things or events, but we cannot recall the details of that object or event. Obliterate subsumption that occurs after some meaningful learning event is not the same as forgetting that occurs after rote learning. There remain some enriched concepts and propositions in your cognitive structure and these will facilitate new, relevant learning. When forgetting occurs after rote learning, there is usually interference or retarded learning of related material. No doubt the reader can recall being confused in trying to recall something recently learned because of the new ideas are still jumbled up with similar things in our minds and we cannot sort out the details.

The fifth principle in Ausubel's (1963) theory is superordinate learning. This kind of learning occurs when several concepts or propositions are recognized as subordinate units of some larger, more inclusive idea. For example, children learn that there are pigs, cows, dogs, and similar animals. When they acquire the superordinate concept of mammal, i.e., something with hair or fur and females with mammary to nurse their young, superordinate learning has occurred. This is useful in the arrangement of concepts in a concept map.

Finally (the sixth principle), there is Ausubel's principle of integrative reconciliation. An example of this principle at work is when a child realizes that multiplication is just a form of repeated addition. The child now sees that 2 x 3 = 6 is the same as 2 + 2 + 2 = 6. So much of mathematics would be more easily learned and remembered if teaching was designed for encouraging repeated integrative reconciliation of component ideas. Of course, this is also true in every other discipline. A general comment about these six principles: Many people have found it difficult to grasp Ausubel's assimilation theory of learning. In part, and in common with the totality of any complex theory in any discipline, this is because each of the principles in this theory is related to all the other principles. One cannot really understand integrative reconciliation until one understands meaningful learning and superordinate learning. One cannot grasp the meaning of all six principles in a single sitting or session. One must get a beginning understanding of each and gradually refine and build those meaning over time with numerous examples and experiences. Profoundly important ideas are profoundly difficult to master.

2.23 Summary

This chapter reviewed literature related to the study. Despite the large amount of research on this topic completed to date, results of existing studies surprisingly show no consistent empirical evidence supporting the link between concept mapping teaching approach and student achievement in biology, as the existing studies have produced mixed findings with some suggesting a positive relationship and others suggesting no relationship in various subject areas. Therefore, a conclusion cannot yet be drawn as to whether concept mapping in biology positively influence students' achievement. Additional research is, therefore, necessary in order to make conclusive judgement about the link between concept mapping teaching approach and students' achievement in biology.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Overview

This chapter outlines the research design, population and sample procedures, instruments, validity, and reliability of the instruments. It also outlines data collection procedure and methods of data analysis and interpretation.

3.1 Research Design

The study adopted action research deign, with a pre-intervention test, an intervention and a post-intervention test designed to improve students' performance in photosynthesis, cellular respiration, and transport in plants (biology). Action research design was chosen amidst all the other research design methods available because it makes for practical problem-solving as well as expanding scientific knowledge, enhances the competencies of participants and is undertaken directly in situ (Cohen, Manion & Morrison, 2012). The design of the study is summarised in Figure 8.

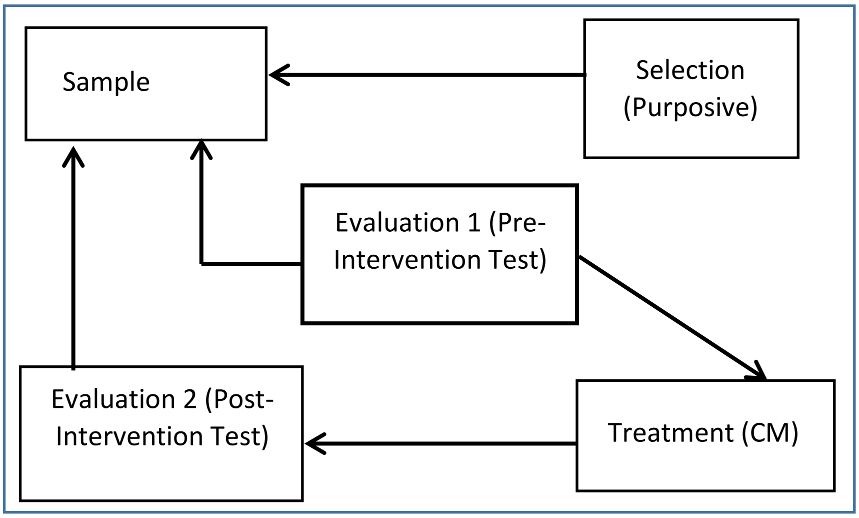

Figure 8: Research Deign

3.2 Population of the Study

The study was designed to enhance the understanding of form three Senior High School students in the following biology concepts: photosynthesis, cellular respiration, and transport in plants. The target population of the study include all senior high school students within the Bono-East Region. The accessible population, however, include all senior high school students within the Nkoranza-North district of the Bono-East Region.

3.3 Research Sample

Out of the accessible population, Osei-Bonsu senior high school was conveniently selected to participate in the study. Osei-Bonu senior high school was selected because it is the school where the researcher teaches. An intact class of forty-two (42) final year science students were purposively elected to form the sample of the study. Form three science students were purposively selected for this study because they were the only stable class at the time the study was being conducted. They were not running the track system; therefore, it was easy to get access to all the student at a time. Moreover, form three science students were the only students who have already covered the concepts of interest to investigate. Thus, it was easier to assess them in a pre-intervention test before administering the intervention. Twenty-two of the sample selected are males whereas twenty of them are females.

Table 1: Distribution of Respondents by Sex

	Males		Female	
	(n)	(%)	(n)	(%)
Research Sample	22	52	20	48
Total	**42(100%)**			

3.4 Instrumentation

Tests were the main instruments used to collect data for this study. A pre-intervention test was used to assess the achievement of students before the intervention and a post-intervention test was used to assess the performance of the students after the intervention was rolled out. Both tests consisted of forty objective test items selected from past WASSCE questions. The post-intervention test and the pre-intervention test were equivalent in terms of difficulty, but contained different items. The post-intervention test was twofold; the first was conducted immediately after the intervention to assess students' achievement after the intervention. Two weeks after, the same test was administered to the students unannounced, in order to assess their ability to recall.

3.5 Validity of the Instruments

According to Bybee (2014), validity refers to the extent to which an empirical measure adequately reflects the real meaning of the concept under consideration. There are various types of validity, which include construct validity, content validity, criterion-related validity, and face validity (Gall & Borg, 2007). Of these, content validity, defined as the degree to which a measure covers the range of meanings included in a concept (Bybee, 2014), was considered relevant. To determine the content validity of the research instruments, three biology teachers reviewed the items to assess whether:

- Only the concepts relevant to the study were examined
- The instruments were suitable for use by high school learners.
- There were no factual errors.
- The items covered the entire concepts taught sufficiently and proportionally.

The three teachers who reviewed the item consisted of one male and two females, all of whom hold a Master's degree in science education. The teachers were selected based on their expertise and experience in the teaching of biology.

All three assessors agreed that the item met the stated requirements. However, some assessors commented on the length of certain narratives and suggested the inclusion of certain concepts in photosynthesis, and removal of others. They also recommended the removal of certain phrases and terms considered difficult for learners. Comments from the assessors were used to revise the items.

3.6 Reliability of the Instruments

Thirty-six form three students (18 boys and 18 girls) participated in a pilot study. They were randomly selected from classes that were not chosen for involvement in the main study. The purposes of the pilot study were:

- To collect data for further review and improvement of the instruments
- To determine the approximate effective duration for each instrument
- To collect data for determining the reliability of the instruments
- To check for logistic problems and errors before conducting the main study

Learners were made aware of the purpose of the pilot study, their role in it, the anonymity and confidentiality of measures and the results, and their right to decline to participate if they wished.

The items were administered to the participants of the pilot study twice. The time gap between the two administrations of the instruments was two weeks. The duration of two weeks was considered short enough for learners not to have gained considerable amounts of new knowledge at the second administration of the instruments, and sufficiently long for them not to remember their previous responses (in the first administration of the instruments).

The results from the first administration of the instruments were used to review the items of the instruments in order to improve them and to determine the approximate duration of each instrument. Results from the second administration of the instruments were used to further review the items and the duration of the instruments. Data from the first and second administrations of the instruments were used to compute the reliability of the instruments. A reliability co-efficient close to one (i.e., 0.87) was recorded, signifying a high reliability of the instruments. The test-retest method of testing reliability, which involves measuring the same object or phenomenon more than once, using the same technique or instrument (Field, 2019), was, therefore, used to test the reliabilities of the instruments in this study. This concept can be seen in Figure 9.

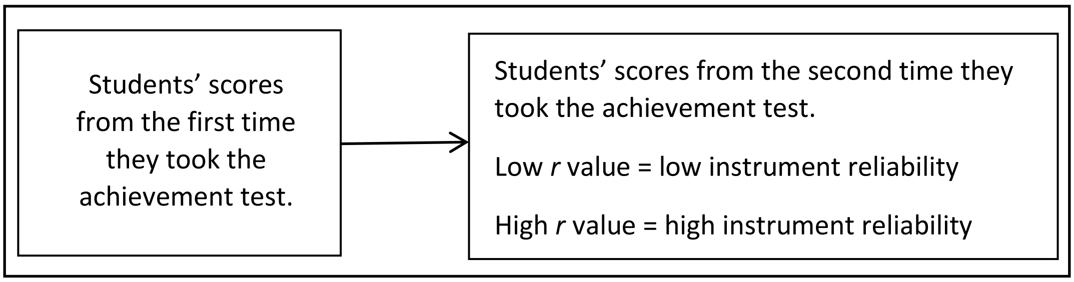

Figure 9: Instrument Reliability

3.7 Intervention

An intervention was drawn up to improve the achievement of students in some selected biology topics. The intervention was carried out within six weeks. The topics covered were photosynthesis, transport in plants and cellular respiration. For the purposes of convenience, some lessons were conducted outside of the usual contact hours.

This study was conducted in the second semester of 2021 academic year. The researcher acted as both a teacher and a researcher. That means the teaching learning process was also conducted by the researcher. The lesson was given regularly three periods in a week. The teacher researcher used a hierarchical type of concept map by giving priority to the most general concepts at the top of the map and sub-concepts at the bottom. This was based on meaningful learning theory that stated concepts are arranged in long term memory in hierarchical maps.

3.7.1 Week one

The treatment period was divided into two parts. The first part consisted of one week during which the students were trained to construct concept maps. One preliminary session was conducted at the beginning of the week to introduce concept mapping, then an example of a concept map was provided followed by guided practice. For the rest of the week students were accorded, towards the end of each session, some time to practice the construction of concept maps using a concept list provided by the researcher. The concept lists were related to the material taught in class, they included biology concepts known to students in order to help them focus on learning the process of concept mapping. Students received feedback on their concept maps. Students were also required to construct concept maps using concept lists identified in class. These concept maps were scored using a scoring rubric developed by the researcher and given back to the students. The scored maps included detailed feedback to help students improve their concept mapping skills. At the end of the first week, the second part of the treatment started and the students were exposed to the main concept, using the concept mapping method, which took five more weeks to complete.

3.7.2 Week two

During the second week of this study, a lesson was designed and presented on transport of materials in plants. Prior to the commencement of the lesson, the researcher asked two questions as a means of introduction. The researcher asked the students to describe the process of uptake and movement of water and mineral salts in plants. The students responded as water and mineral salts are taken up from the soil by the plant roots and sent to the other parts of the plant through the stem. The researcher also asked the students how food produced through photosynthesis reach the other parts of the plant. The students responded by saying the food produced and stored in the leaves is carried through the stem to the roots and other parts of the plant.

The students could not answer the questions by referring to the tissues and organs involved in the transport of materials in plant. The students considered the stem of the plant as a single large vessel performing the function of transporting all kinds of materials. They failed to identify that transport of different kinds of materials is done by different specialised tissues such as phloem and xylem tissues within the plant.

The researcher presented concept maps with which he taught the students about different parts of the plant and their functions. The concept maps used to facilitate this lesson are shown in Figure 10 and Figure 11.

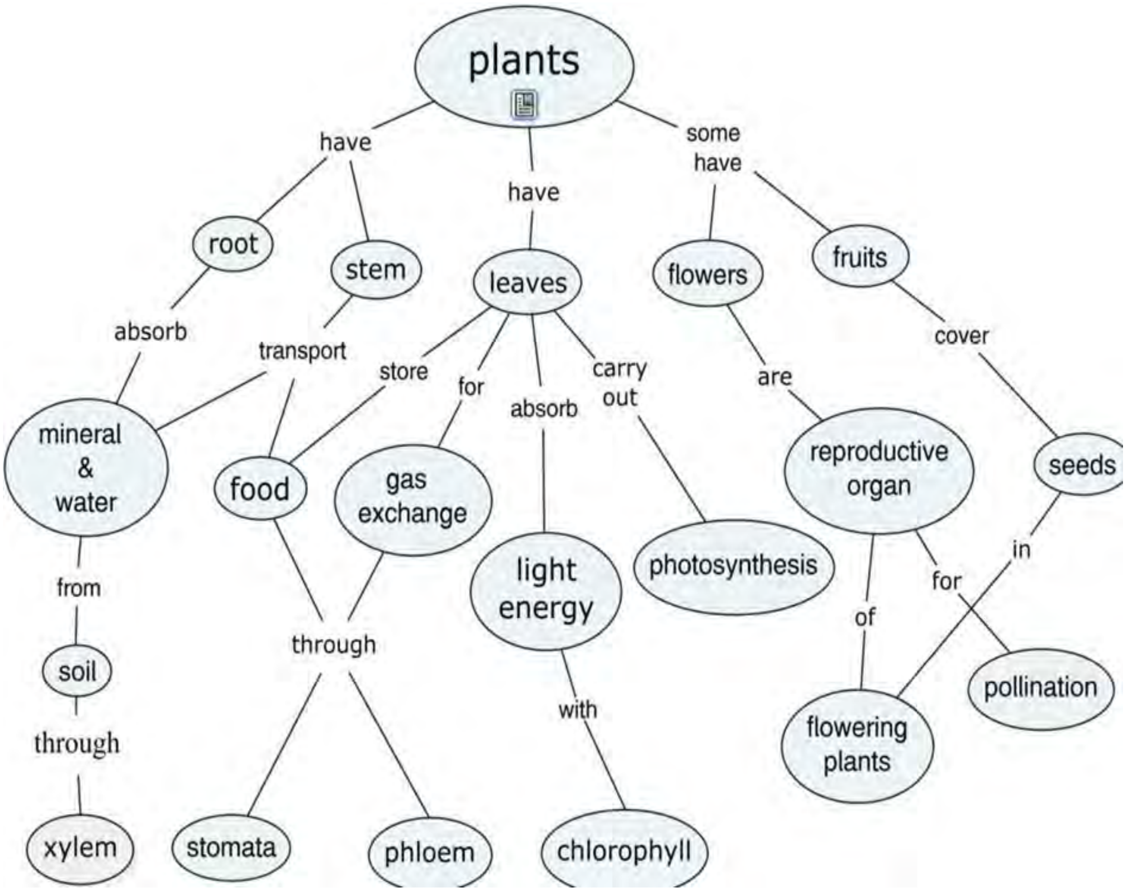

Figure 10: Concept Map on Parts of Leaves and their Function (Yenenesh et al., 2020)

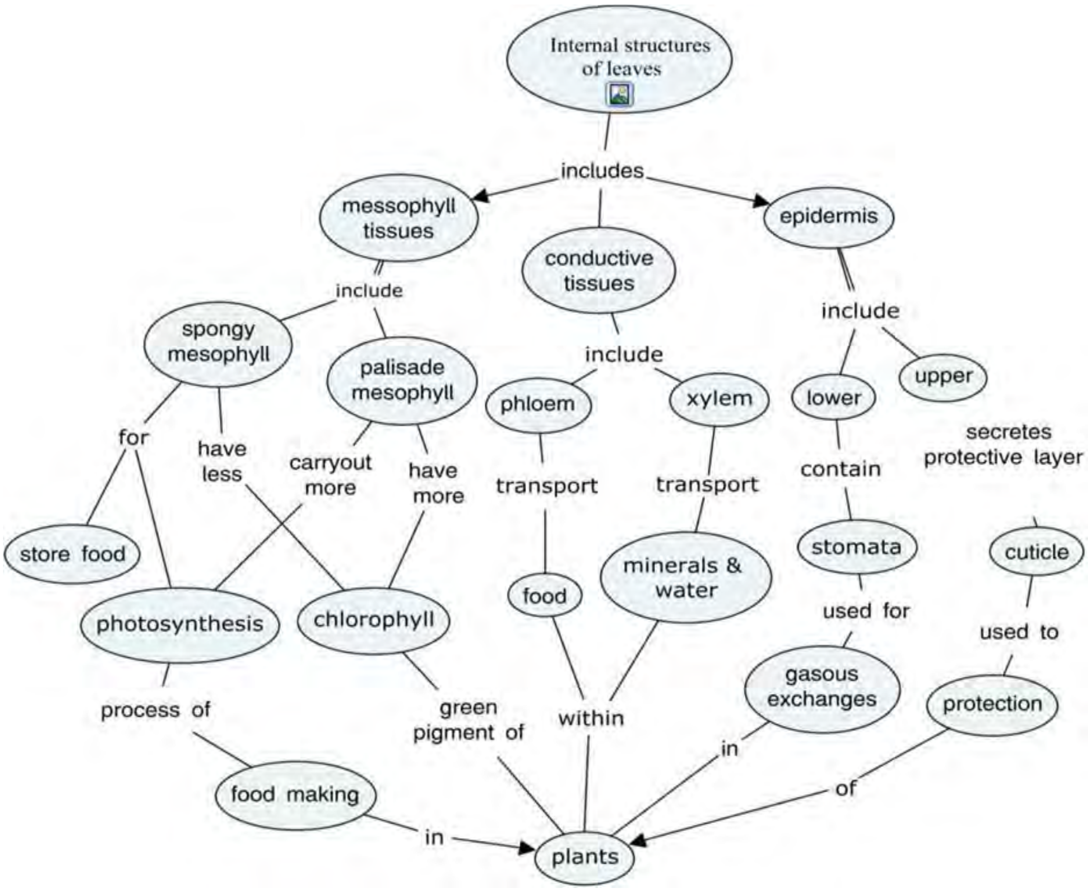

Figure 11: Concept Map on Internal structures of Leaves and their Function (Yenenesh et al., 2020)

After minutes of illustration and explanation, students were guided to construct concept maps on the topic from their text books. Feedback was given to students on their concept maps and the lesson was evaluated and closed.

3.7.3 Weeks three and four

During weeks three and four, lessons were presented on photosynthesis and processes of photosynthesis respectively. The researcher conducted informal assessment before the intervention to examine students' understanding and misunderstanding of concepts related to photosynthesis by asking verbal questions. As results from the informal assessment indicated most of the students' responses falls into the same ideas. For instance, the first question was how plants make their own food? Students' reflection for this question is ―plants can make their food by using soil, light and water". This response indicated that students have an idea that plants can make their own food but have no detailed understanding about the process of photosynthesis, that is, how soil, light and water are involved.

For the second question; what is the concept of photosynthesis? Students answered that ―Photosynthesis is the process of making food in plants." Both the first and the second questions examine students' idea about food making in plants, and the process of food making in plants (materials for making food, process, and products of photosynthesis). Here students have an idea about what photosynthesis means but have no in depth understanding about it because they cannot give further explanations.

In the third question the main concern is how students relate photosynthesis with the global warming. How photosynthesis can help to reduce global warming? This can help to examine students understanding of the concept of photosynthesis and how they relate it to daily life. In response to this question, students answered that ―Photosynthesis can reduce global warming by releasing oxygen to the atmosphere". This response indicated that students have an idea that plants can produce oxygen during photosynthesis and this is released into the atmosphere but they have no an idea that plants instead can absorb carbon dioxide during photosynthesis. This is one means of reducing the amount of carbon dioxide from the atmosphere and this can help to understand how photosynthesis can decrease global warming.

The last question; what is the purpose of plants to carryout photosynthesis? This question aims to examine the assumption of students on why plants carryout photosynthesis. The students' reflection on this question is; -the purpose of photosynthesis is to produce oxygen." But the main purpose of plants carrying out photosynthesis is for the synthesis of their own food (glucose). Indeed, plants can release oxygen during photosynthesis and this oxygen is important for animals including humans.

With regards to the first and second questions, some students thought that plants cannot make their own food instead they get their food from the soil instead. That means plants directly feed on soil. In addition, few students thought that plants are non-living things. These ideas of students indicate that the concept of photosynthesis is not clear. Consequently, after the students' understanding and gaps were identified, the interventions were carried using the concept mapping-based teaching. Some of the concept maps that were constructed and used to aid the lesson are presented in Figure 12, Figure 13, and Figure 14.

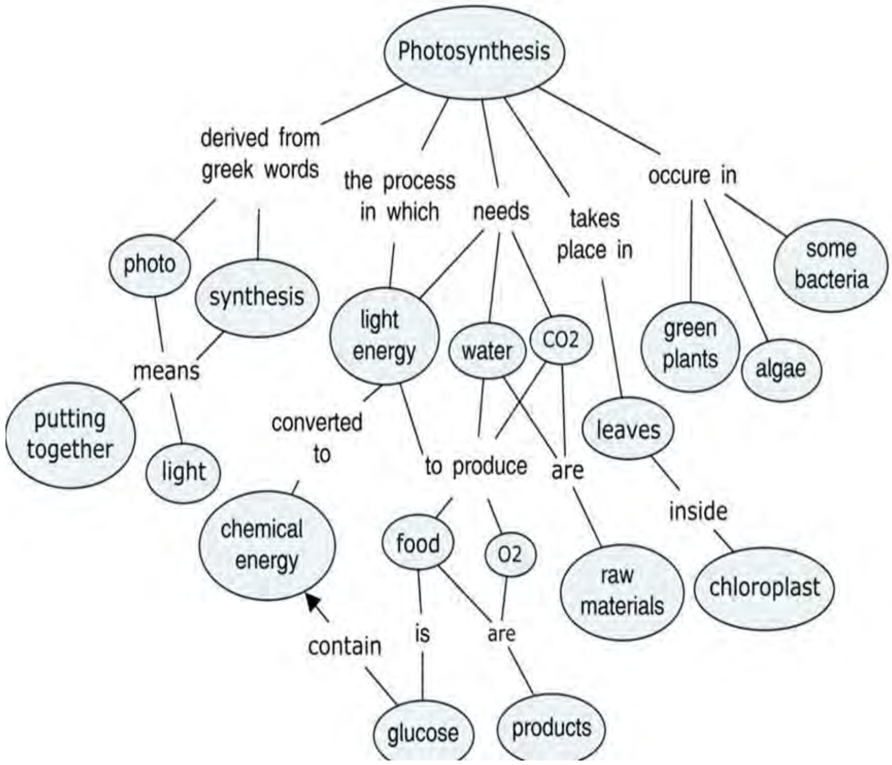

Figure 12: Concept Map on Photosynthesis (Yenenesh et al., 2020)

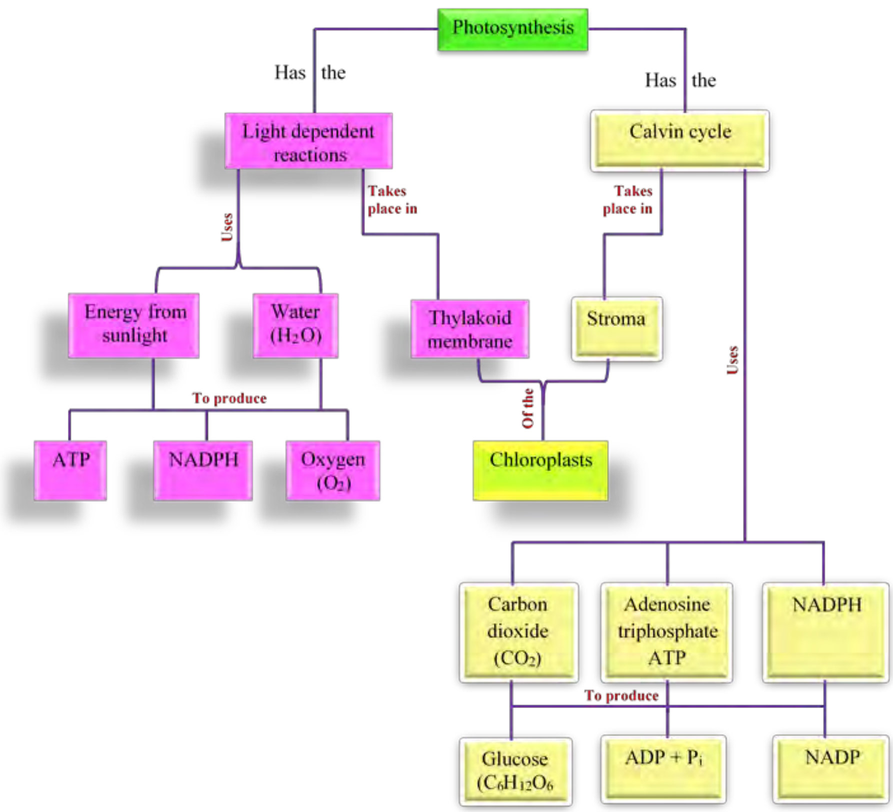

Figure 13: Concept Map on Photosynthesis

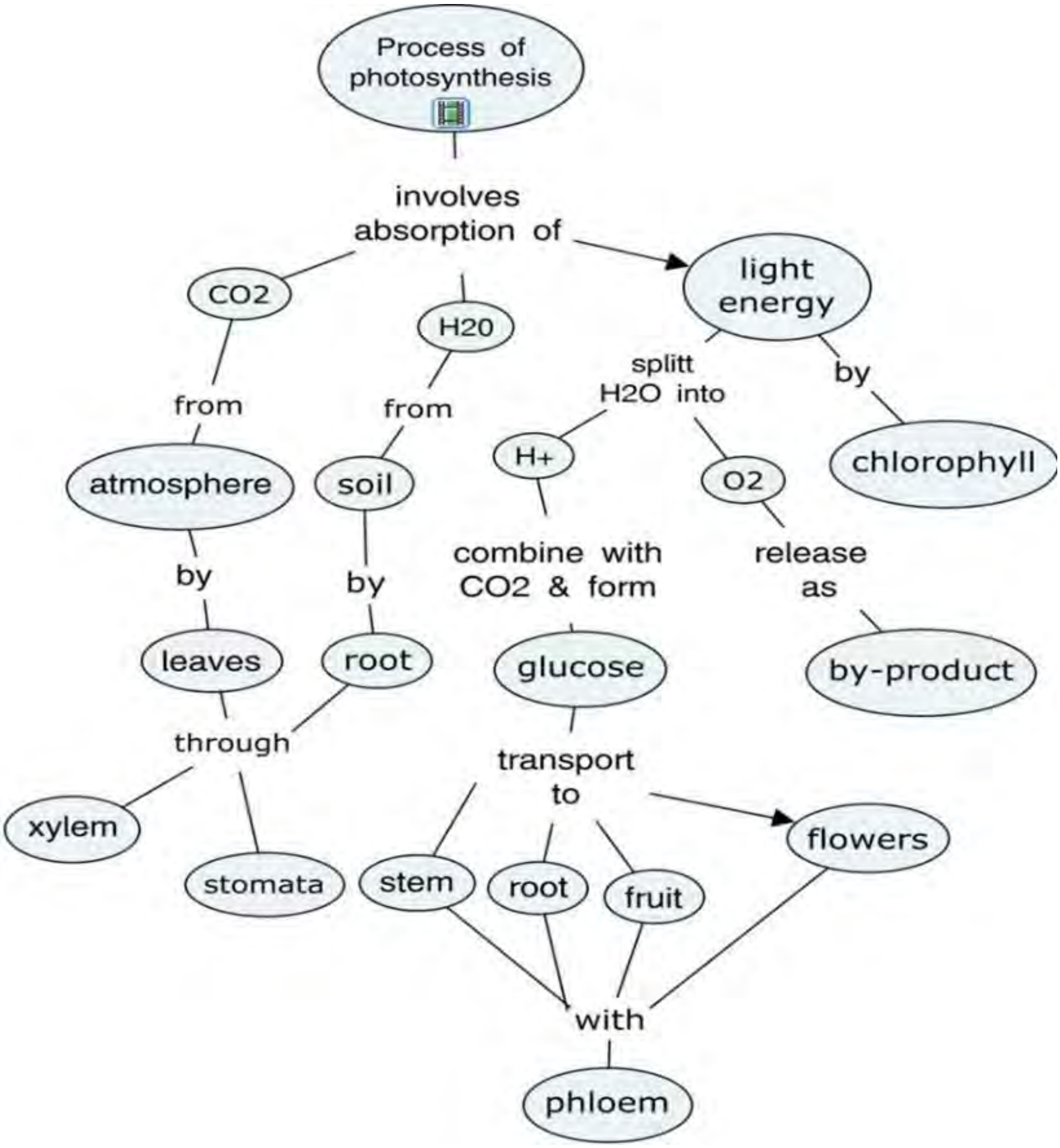

Figure 14: Concept Map on Processes of Photosynthesis (source: adopted from Yenenesh et al., 2020)

After students were taken through these concept maps on photosynthesis and the processes of photosynthesis, they were guided by the teacher to construct their own concept maps after which they were evaluated on the concept maps presented to them and the concepts taught.

3.7.4 Week five

In the sixth week of the intervention, a lesson was prepared and presented on cellular respiration. A concept map was constructed to show the various stages involved in cellular respiration. Cellular respiration includes the series of chemical reactions needed to break down (metabolize) carbohydrates and other molecules in order to release the energy they contain. The energy released by cellular respiration is stored in the form of the energy carrier molecule, adenosine triphosphate (ATP). This important molecule provides the energy for muscles to contract, nerves to conduct impulses, and all that cells require to build protein, pump in substances they need, permit enzymes to act, and so on. Energy is released one ATP molecule at a time, as the cell requires it. Glucose and other molecules are broken down mainly in the mitochondria of cells, producing ATP molecules. All organisms perform cellular respiration, and almost all organisms carry out the process of aerobic cellular respiration in their mitochondria.

Aerobic means that the process requires oxygen. Aerobic cellular respiration consists of four main phases, as summarised in Figure 15. Through the whole four-phase process, cellular respiration of one glucose molecule produces 38 molecules of ATP in bacterial cells and 36 molecules of ATP in cells with mitochondria. In eukaryotic cells, two ATPs of energy are lost to intermediate energy carrier molecules. The usable energy of ATP is stored when the energy from cellular respiration chemically bonds a third phosphate group to a molecule that is already present, called adenosine diphosphate (ADP). The bonding of a third phosphate (P) to the two phosphate ADP molecule is what produces the three-phosphate ATP molecule. This ATP can now release energy for cell activities, when its third phosphate group breaks off. Perhaps surprisingly, the phosphate-to-phosphate bond in ATP, between the second and third phosphate groups is relatively weak — less than 10% as strong as a carbon-to-hydrogen covalent bond, for example. Nevertheless, the amount of energy released by breaking the phosphate-to-phosphate bonds is enough to drive essential cell reactions. In fact, the low energy phosphate-to-phosphate bond is extremely valuable precisely because it is easily broken and the release of energy within a cell can be adjusted to suit the cell's exact requirements. After the third phosphate group breaks off, the ATP molecule reverts to the lower energy ADP molecule, available to accept another phosphate group, producing the ATP molecule, once again. This process continues over and over in every cell, so long as oxygen and molecules of foods are available for the process of cellular respiration to continue.

Glycolysis takes place in the cytoplasm of the cell, not in the mitochondria. Glycolysis is the breakdown of glucose into two pyruvate molecules, and it does not use oxygen. All organisms perform glycolysis, but only a small fraction of the available chemical energy is released by this phase (just two ATP molecules from one glucose molecule). What happens next will depend on two factors:

1. The type of organism. Some micro-organisms lack the cell parts and enzymes to perform the aerobic phases of cellular respiration. The Krebs cycle and electron transport do not occur in these organisms.

2. The availability of oxygen. Even in cells with many mitochondria, a continuous supply of oxygen is needed to sustain a continuous release of energy. If the oxygen supply is deficient, such cells cannot carry out the Krebs cycle; hence electron transport cannot occur. In either of these cases, the cell may use an alternative process to release further chemical energy from its food molecules.

Some types of cells can also release energy through the process of fermentation. Fermentation includes glycolysis, but not the other parts of aerobic cellular respiration. In fermentation, glycolysis is followed by one of two pathways: the pyruvate formed breaks down to become either lactate or alcohol, depending on the organism. Both glycolysis and fermentation are anaerobic processes: they occur in the absence of oxygen.

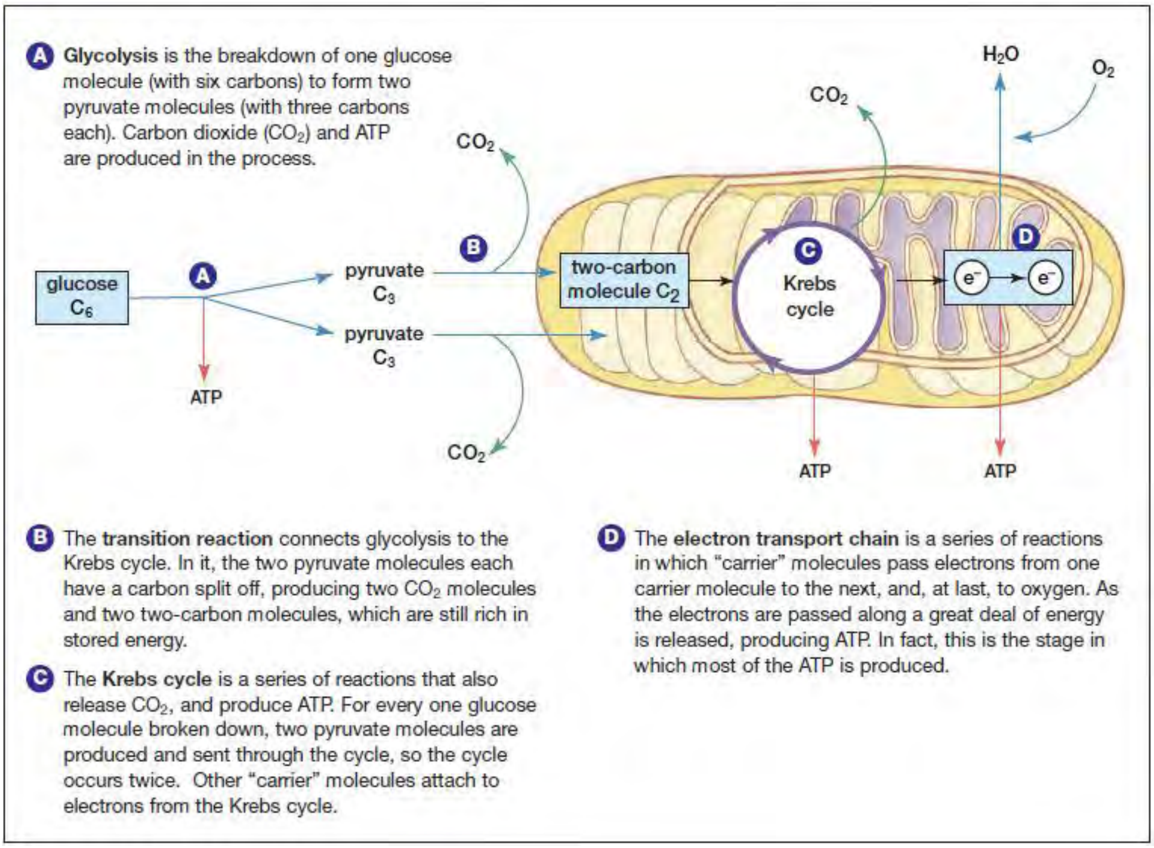

Figure 15: Cellular respiration (source: Ryerson, 2014)

The students were taken through the concept map shown in Figure 16 Following that they were guided to construct concept maps using the concepts taught them. Their concept maps were evaluated and feedback provided. Their understanding of the concepts taught was then assessed. The intervention continued in the sixth week.

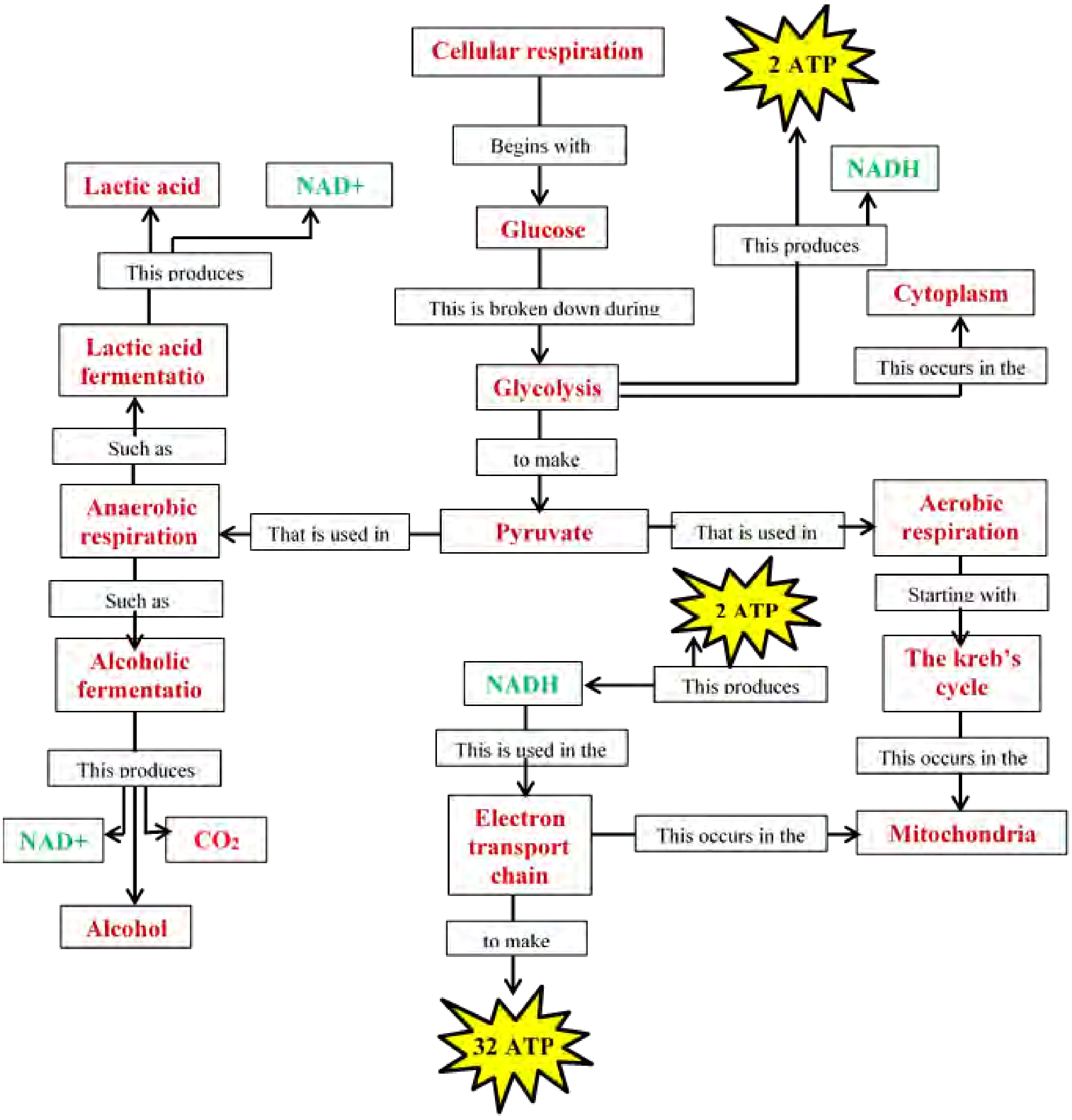

Figure 16: Concept Map on Cellular Respiration

3.7.5 Week six

During week six of the study, the focus was on the students' mastery of constructing concept maps and on assessing the students' understanding of the concepts taught from week two to five. Students were required to construct concept maps using concepts taught in class. The teacher did not provide the list of concepts to the students. Each student was required to construct three different concept maps based on three different concepts. These exercises were scored and the students were provided with detailed feedback. At the end of the treatment period, the students were post-tested.

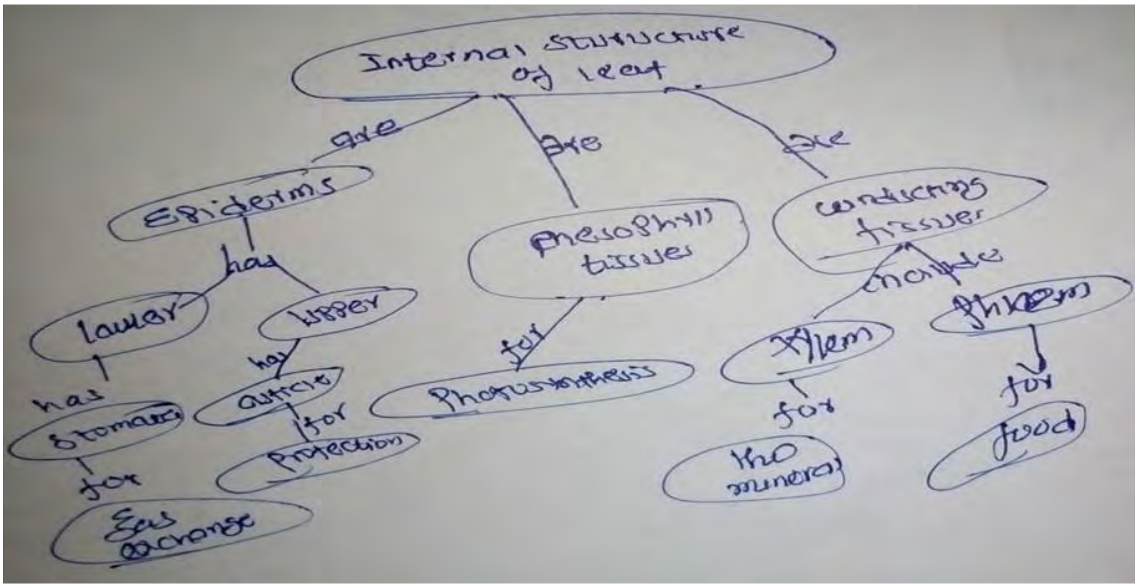

Figure 17: Concept Map Constructed by a Student

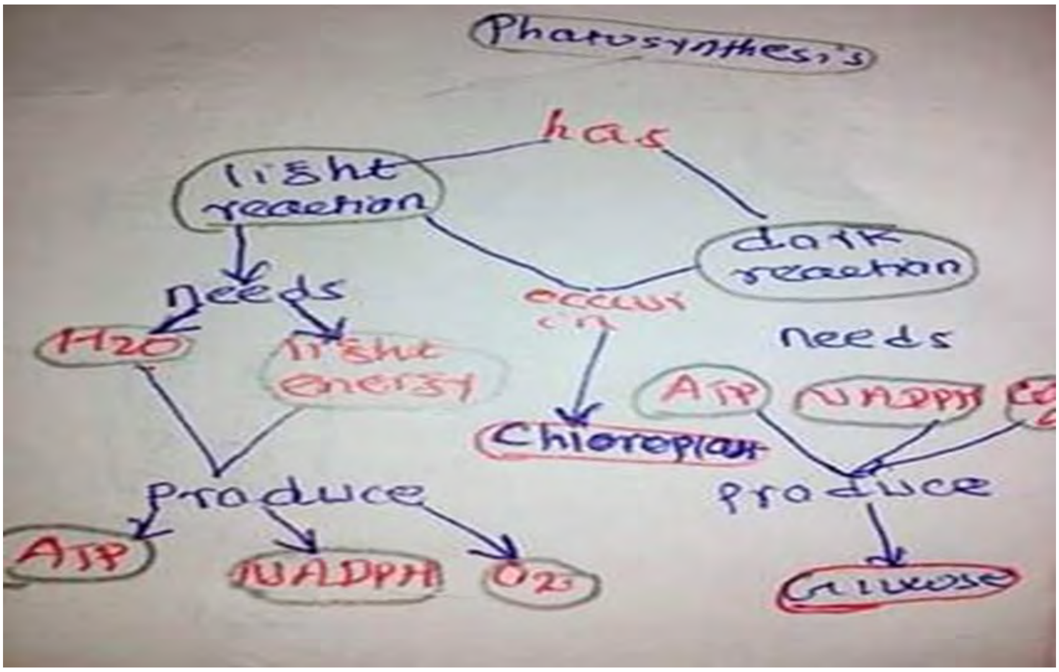

Figure 18: Concept Map Constructed by a Student

3.8 Data Collection Procedure

To enhance the understanding of some senior high school students in the concepts of photosynthesis, cellular respiration and transport in plants, a study was planned and carried out at Osei-Bonsu senior high school in the Bono-East Region of Ghana. One treatment style, concept mapping method of teaching, was applied during the intervention. Prior to the intervention, a pre-intervention test was administered to the participants of the study to ascertain their achievements in the relevant concepts. The outcomes of this test were collected and stored. For six weeks, the participants were given instruction in biology on the relevant concepts using the concept mapping method of teaching. After the treatment, a post-intervention test was administered to the students. The scores obtained by the students on the post-intervention test was also recorded and stored. Two weeks after the administration of the post-intervention test, the same test was given to the students unannounced, to assess the ability of the students to recall information that they have learned during the intervention. Data collected from the administration of this test, together with those collected and stored earlier were organised and used to statistically test the null hypotheses that were formulated prior at 0.05 significance level.

3.9 Data Analysis Technique

Microsoft Excel (2016) and SPSS statistical tools were used to test the null hypotheses at 0.05 level of significance. T- test was employed to validate the significant difference in the raw gains between the pre and post intervention tests. Where necessary, measures of central tendency (i.e., mean, mode and median) were calculated. Analysis of Variance, ANOVA was used to analyse the extent of variation between the achievement of males and females on the post-intervention test.

Table 2: Data Collection and Analyses Technique

Research Questions	Sources of Data	Data Collection Technique	Data Analyses Technique
1. What is the effect of concept mapping teaching method on senior high school students' academic achievement in biology?	Students	Pre and Post Intervention Tests	t-Test, Frequency/Percentage counts
2. What is the effect of concept mapping on senior high school students' retention ability?	Students	Post Intervention Test	ANOVA
3. What is the influence of gender on senior high school students' academic achievement when taught biology using concept mapping method?	Students	Post Intervention Test	t-Test

3.10 Ethical Issues

Ethics in educational research are those issues that are related to how educational researchers conduct themselves and consequences of these on the people who participate in their research (Kusi, 2012). The researcher ensured that prospective participants were made aware of the purpose of the study and their rights as a participant. Following that, prospective participants were requested to provide a written acknowledgement of their agreement to participate in the study. Also, permission was sought from the school authorities before the commencement of the study. All data collected will be kept and destroyed after four years.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This chapter is divided into three sections. The first section presents the demographic study of the participants of the study. The second section presents the findings that emanated from this study based on research questions and the concluding section presents the discussion of the findings.

4.1. Demographic Data

The tables below present the demographic study of the research participants. A total of 42 final-year science students participated in the study. Out of this number, 22 of them, representing 52% were males whereas the remaining 20, representing 48% were female students. Table 3 summarises this data.

Table 3: Sex of Forty-two Students

Sex	Males	Females
Frequency (%)	22 (52%)	20 (48%0)
Total	**42 (100%)**	

Five students, (three males, two females) were aged between ten and sixteen, thirty-one (15 boys, 16 girls) were aged between fifteen and twenty-one and six students (four males and two females) were aged between twenty and twenty-six. The average age of the students was between sixteen and twenty. This information is presented in Table 4.

Table 4: Age of Students

Age	Male	Female
11-15	3	2
16-20	15	16
21-25	4	2

4.2 Research Question One

What is the effect of concept mapping teaching method on senior high school students' academic achievement in biology?

H_{O1}. There is no statistically significant difference between students' academic achievement in biology before and after the use of concept mapping method to teach biology.

This research question sought to assess the impact that concept mapping approach had on the academic achievements of the students. To answer this research question, a pre-intervention test was administered to the students. Following that, a six-week intervention was rolled out to them and a post intervention test was then administered.

The scores obtained by the students on the pre and post intervention tests are displayed in Table 5. It is observed from the table that prior to the administration of the intervention, when the students were assessed in the selected concepts, they obtained scores between forty and seventy-one, with many of the students scoring between fifty and seventy. Again, it seen from the table that after the intervention, the performance of the students has improved, with the majority scoring between seventy and ninety.

Table 5: Pre- and Post-Intervention Test Scores

Scores	Frequency (Pre-Intervention)	Frequency (Post-Intervention)
41-50	7	--
51-60	15	--
61-70	19	4
71-80	1	25
81-90	--	13
91-100	--	--
Total	**42**	**42**

The information in Table 5 is summarised in Figure 19. It is seen from Figure 19 that before the intervention, the performance of the students was lower than their performance after the intervention. Seven students scored between forty and fifty on the pre-intervention test. Fifteen students scored between fifty and sixty on the pre-intervention test, nineteen of the students scored between sixty and seventy and one person scored between seventy and eighty. Most of the students had scores between fifty and seventy. It is also worth mentioning that none of the students scored between eighty and hundred on the pre-intervention test. However, the performance of the students had improved when they were assessed in a post-intervention test after they have been taught biology using concept mapping technique. As seen from Figure 19, none of the students scored between forty and sixty on the post-intervention test. Four of the students scored between sixty and seventy on the post-intervention test and most of the students (thirty-eight) had scores between seventy and ninety.

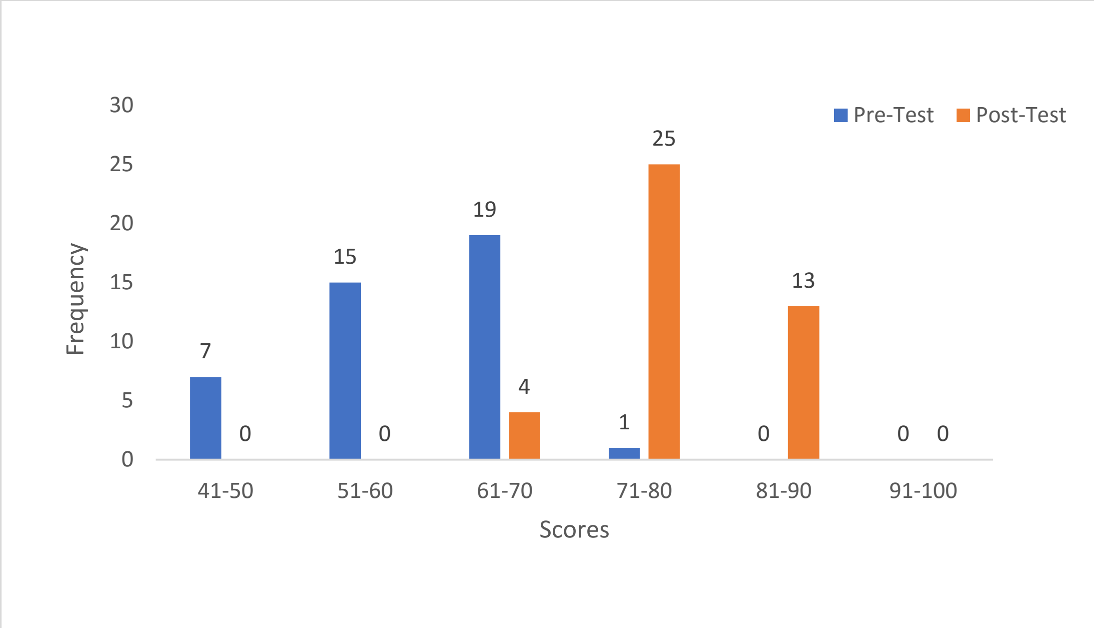

Figure 19: Students' Scores on Pre- and Post-Intervention Test

Specifically, research question one sought to find out whether there exists a significant difference between the performance of the students on the pre and post intervention tests. The following null hypothesis was formulated in that regard: There is no statistically significant difference between students' academic achievement in biology before and after the use of concept mapping method to teach biology. To test this hypothesis, a paired sample t-test was conducted at an alpha level of 0.05 to assess whether there was a significant difference between students achievement on the pre-test and their achievement on the post-test. The result from the t-test is presented in Table 6.

The test found a statistically-significant difference between the performance of the students on the pre and post intervention tests conducted before and after the use of concept mapping teaching approach respectively (P(one-tail) = 2.54E-17, < 0.05). Comparing the variance of the pre-intervention test and that of the post-intervention test (63.42 > 25.06), it is inferred that more students had scores closer to the mean mark (77.76) in the post-intervention test as opposed to their achievements on the pre-intervention test that recorded scores less than the mean mark (58.40). Hence, it is concluded that the statistical difference observed by the t-test conducted was in favour of the post-intervention test. Based on this result, the null hypothesis stating that there is no statistically significant difference between students' academic achievement in biology before and after the use of concept mapping method to teach biology was rejected. An alternative hypothesis was thus formulated as the mean score of students on the post-intervention test is greater than that on the pre-intervention test.

Table 6: t-Test; Paired Two Sample for Means

	Pre-Test Scores	**Post-Test Scores**
Mean	58.4047619	77.76190476
Variance	63.41753775	25.06387921
Observations	42	42
df	41	
t Stat	-13.81727574	
P(T<=t) one-tail	2.53932E-17	
t Critical one-tail	1.682878002	

The mean performance of the students is summarised in Figure 20.

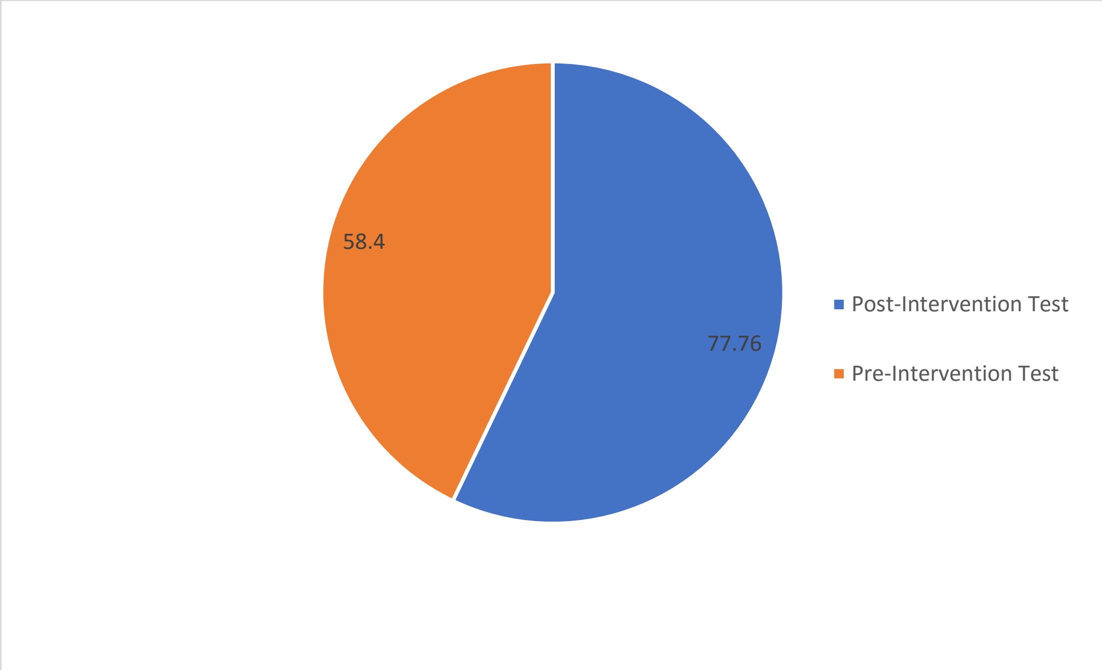

Figure 20: Mean Performance of Students

4.3 Research Question Two

What is the effect of concept mapping on senior high school students' retention ability?

H_{O2}. The mean achievements of students on the pre-intervention test, post-intervention test and the retention test is the same.

This research question sought to assess the impact of concept mapping teaching approach on the capacity of students to recall information. To answer this research question, the post-intervention test that was organised for the students was re-administered two weeks after the students took the original test. The idea here was to assess whether the student could recall concepts that they were taught during the intervention period. The outcome of this test was compared to the results obtained on the pre-intervention and the post-intervention tests using the Analysis of Variance (ANOVA) technique. The result from the test follows next.

There was a statistically-significant difference in the mean performance of the students on the tests (F (stat) = 145.64, p (3.68E-33) < 0.05). The larger the F-value, the more likely it is that the variation associated with the mean marks is real and not due to chance. An F-value of 145.64 sufficiently suggests that the variation associated with the students' scores on the tests was not by chance. Because the p-value is significant ($p < 0.05$), it is concluded that at least one of the means is significantly different from the others (Table 7).

Table 7: ANOVA Table

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	10569.571	2	5284.786	145.637	3.681E-33	3.070
Within Groups	4463.357	123	36.287			
Total	**15032.929**	**125**				

A Tukey post-hoc test revealed significant pairwise differences between the tests.

The Tukey post-hoc test revealed significant differences between the pre-intervention test (A) scores and the post-intervention test (B) scores (19.36 > 3.43), with an average difference of 19.36% and between the pre-intervention test (A) scores and the retention test (C) scores (19.50 > 3.43), with an average difference of 19.50%. The Tukey HSD test also revealed no significance difference between the test scores obtained on the post-intervention test (B) and those obtained on the retention test (C) (0.14 < 3.43). It is clear from Table 8 that the students could recall concepts taught to them during the intervention weeks after the intervention and their performance on the retention test was like that on the post-intervention test. The results of the Tukey HSD test are presented in Table 8.

Table 8: Tukey HSD Test

Pair	$\bar{x}_1 - \bar{x}_2$	Critical value	Significant at α = 5%?
A & B	19.36	3.43	Yes
A & C	19.50	3.43	Yes
B & C	0.14	3.43	No

***A = pre-intervention test *B = post-intervention test *C = retention test**

4.4 Research Question Three

What is the influence of gender on senior high school students' academic achievement when taught biology using concept mapping method?

H_{O3}. There is no statistically significant difference between the achievements of male and female senior high school students on the post-intervention test when biology was taught using concept mapping method of teaching.

This research question sought to assess the influence of sex on the academic achievements of the students. To answer this research question, the performance of the male and female students on the pre and post intervention tests was compared. Before the intervention, the students were administered a pre-intervention test based on the concepts that would later be taught. The scores obtained by the students on the pre-intervention test are displayed in Table 9. It is observed from the table that prior to the administration of the intervention, when the students were assessed in the selected concepts, the male students obtained scores from forty-one to seventy, with many of them obtaining between fifty and sixty-one. The female students, on the other hand, obtained scores between forty-one and seventy-one, with most of them obtaining scores between sixty and seventy-one.

Table 9: Pre-Intervention Test Scores

Pre-test Scores	**Frequency (males)**	**Frequency (females)**
41-50	4	3
51-60	10	5
61-70	8	11
71-80	--	1
81-90	--	--
91-100	--	--
Total	**22**	**20**

Figure 21 shows the distribution of pre-intervention test scores among male and female students. The scores of the male students range from 41-70 while that of the female students are from 41-71. As seen from Figure 21, only one student (2.4%) among the females scored the highest (71). It is seen from the Figure 21 that before the intervention, the performance of the students was quite low with no student scoring above seventy-one.

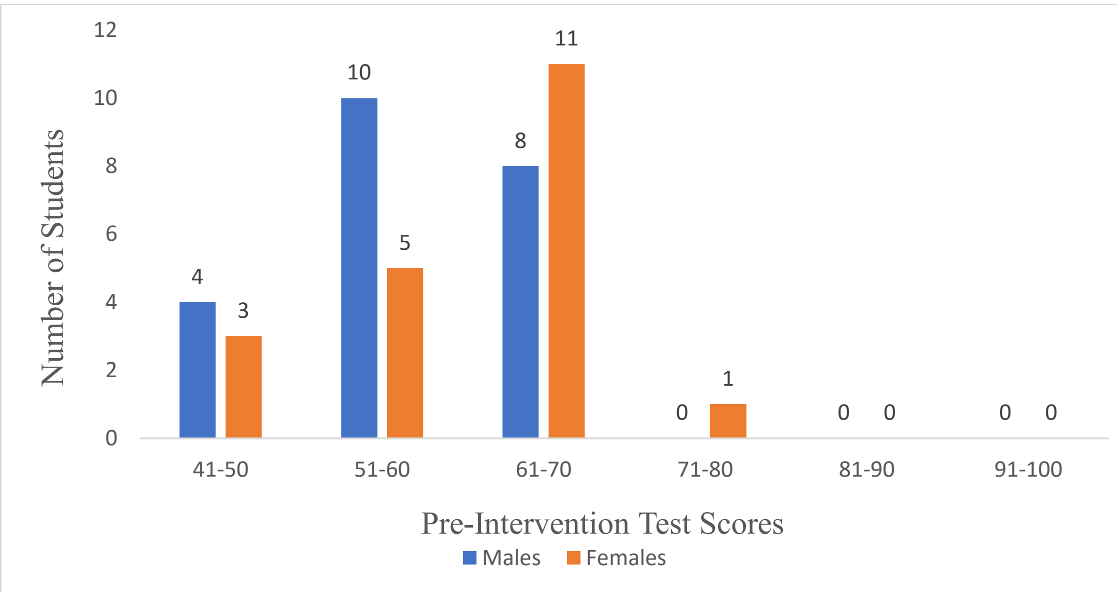

Figure 21: Pre-Intervention Test Scores of Male and Female Students Compared

To compare and verify if the pre-intervention test scores of the male students and the female students were statistically the same, a two-tailed t-test was run. The result of the test is presented in Table 10.

The test found that the p-value is not significant (p, 0.07 > 0.05). This establishes that all participants had the same prior knowledge of the concepts covered in the pre-intervention assessment.

Table 10: Summary of Statistics on Pre-Intervention Test Scores for Male and Female Students

	Males	**Females**
Mean	56.31818182	60.7
Variance	64.13203463	55.37894737
Observations	22	20
df	40	
t Stat	1.837916582	
P(T<=t) two-tail	0.073509862	
t Critical two-tail	2.02107539	

After six weeks of instruction using the concept mapping approach, a post-intervention test was given to both the male and female students. Table 11 shows the distribution of the post-intervention test scores among the male and female students.

It can be seen from Table 11 that the scores of both the male and female students improved after the intervention, with both groups obtaining scores between sixty and ninety. Also, Table 11 revealed that most students in both groups obtained scores between seventy and eighty.

Table 11: Post-Intervention Test Scores

Post-test Scores	**Frequency (males)**	**Frequency (females)**
41-50	--	--
51-60	--	--
61-70	2	2
71-80	11	14
81-90	9	4
91-100	--	--
Total	**22**	**20**

Figure 22 shows that equal numbers of male and female students obtained scores between sixty (60) and seventy-one (71). However, more females (14) than males (11) obtained scores between seventy and eighty-one. Also, the Figure revealed that more male students (9) as compared to female students (4) scored between eighty and ninety, the highest range of scores recorded. No student scored above ninety marks.

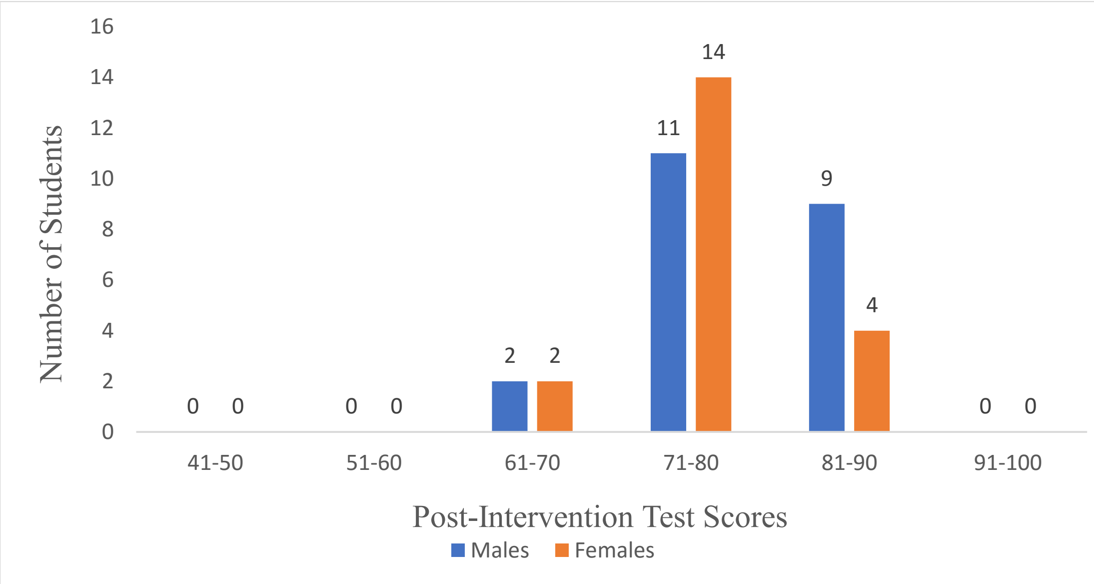

Figure 22: Post-Intervention Test Scores of Male and Female Students Compared

To determine if the difference in the post-intervention test scores of the male and the female students is statistically significant, a t-test was employed. Table 12 shows a summary of the analysis that was conducted.

A p-value of 0.39 renders a decision that the difference in performance of the male and female students on the post intervention test is not statistically significant (p, 0.39 > 0.05). This can be explained that; concept mapping approach did not improve the performance of male students than it did the performance of female students. In other words, the sex of the students had no significant influence on their academic achievements when taught using concept mapping approach. This explanation is valid, more especially when there was no statistical significance between the entry knowledge of male and female students before the administration of the intervention (Table 10). Based on the outcome of this test, the researcher failed to reject the null hypothesis stating that there is no statistically significant difference between the achievements of male and female students on the post-intervention test when biology was taught using concept mapping method.

Table 12: Summary of Statistics on Post-Intervention Test Scores for Male and Female Students

	Males	***Females***
Mean	78.40909091	77.05
Variance	25.49134199	24.89210526
Observations	22	20
df	40	
t Stat	0.876686415	
P(T<=t) two-tail	0.385891905	
t Critical two-tail	2.02107539	

4.5 Discussion

4.5.1 Effect of concept maps on students' performance in biology

This study found that concept mapping is an effective teaching and learning strategy that can be used to improve academic achievement of the students of both genders in biology. The results from the pre-intervention and the post-intervention tests of the students suggest a statistically significant ($p < 0.05$; Table 6) improvement in the performance of the students in favour of the post-intervention test. The post-intervention test was administered only after the intervention was carried out. This explains that concept mapping approach had a positive impact on the academic achievement of students in biology. The results of this study extend the findings of Hall and O'Donnell (2016) that found significant difference between the pre-intervention test scores and the post-intervention test scores of biology students in favour of the post-intervention test scores when they were taught biology using concept mapping technique.

Also, Dhaaka (2012) recommended the use of concept mapping as an effective tool for biology teaching. Along the same vein Udeani and Okafor (2012) maintained that, concept mapping strategy promotes meaningful learning as well as students' academic achievement. A major reason for this finding could be that concept mapping provides opportunity for active involvement of students in their learning process and hence enhances their thinking ability while cross questioning and thinking for seeking solution. Concept mapping facilitates and even stimulates imaginations of the learner (McNaught & Kennedy, 2017). Presentation of the concepts to the fellow students brings a greater conceptual clarity for themselves (Fisher, 1990). During the discussion among the peers, learners became aware of their misconceptions. Inconsistent reasoning leads to cognitive conflict. In normal discourse there is a chance that misconceptions of the learners are gone unchecked. But when concept map is drawn, the misconceptions can be traced very easily by the teacher or by comparing student made concept maps with the scientifically accepted concept maps. Hence it can be said that concept mapping improves academic performance of both male and female students due to their active involvement in learning, discussion, sharing of concepts and removal of misconceptions.

4.5.2 Effect of concept maps on students' retention ability

Regarding students' ability of recalling concepts through constructing concept maps, the present study shows that students taught biology with concept mapping method were able to recall concepts related to biology during and after the intervention. This is seen in their scores on the pre-intervention, post-intervention, and retention tests. When an ANOVA test was conducted to compare their mean achievements on the various tests, the test statistic was found to be significant ($p < 0.05$; Table 7). When a Tukey HSD post-hoc test was used to analyse all possible comparisons of the means, significant differences were revealed between the pre-intervention test and the post-intervention test ($x_1 - x_2$ (19.36) > critical value (3.43)) and the pre-intervention test and the retention test ($x_1 - x_2$ (19.50) > critical value (3.43)). However, there was no significant difference between the post-intervention test and the retention test ($x_1 - x_2$ (0.14) < critical value (3.43)). This implies that student's performance on the retention test is like their performance on the post-intervention test. Hence, it can be said that concept mapping teaching approach had a positive impact on the ability of students to recall information in biology. The result of this concept mapping activities is similar to the findings of Rewey *et al*. (2019) in which concept mapping activities enabled students to relate and show the connection of concepts and synthesis of meaning weeks after their intervention. Hence, concept mapping method fits with constructivist ideas in which students relate concepts and make meanings by themselves. This again is supported by Plotnick (1997) who stated that concept mapping method is a constructivist approach because it includes students in a discovery of knowledge and enhances meaningful learning in science education.

4.5.3 Effect of concept maps on the performance of male and female students in biology

The study also found no gender influence on students' achievement in biology. From the results obtained and tested based on research question three and hypothesis three, it is evident that the mean achievement of male and female students in biology is not significantly different ($p < 0.05$, Table 10; 12). This implies that the difference between the achievement of male and female students in biology is not statistically significant. This further shows that concept mapping may produce the same effect on the mean achievements of the male and female students. The result of this study is contrary to the finding of Huff and Jenkins (2002), who found that sex had significant impact on the achievement of students in biology. This study that provides gender disparity is against other studies which showed that concept mapping is not gender biased. This is since concept mapping presents topics/concepts bit by bit, from known to unknown, shows meaningful relationships between concepts and promotes creative thinking in both male and female students. Concept mapping takes care of individual differences in the students and as well, reduce to the barest minimum the bore on the students when taught with conventional method. This finding, however, agrees with the findings of Jacobs-Lawson and Hershey (2002), Cook (2017), Birbili and Lin (2001), and Eden and Ackerman (2001) who observed that both males and females could do well in biology if exposed to similar learning conditions. The result of the data analysis revealed no interaction between method (concept mapping) and gender on students' achievement in biology.

Furthermore, the finding from the data analysis is supported by the work of BouJaoude and Attieh (2017), who asserted that there was no significant difference when interaction effect of gender and instructional method was explored, showing that the males and females were affected positively by the method. However, the instructional method (concept mapping) seemed to have provided an environment free from stress and boredom in which male and female students have achieved some level of equilibrium. Concept mapping therefore, should be used for teaching both male and female students in biology. This finding, again, agrees with the findings of Kinechin (2000) who reported no gender influence in the acquisition of science process skills when students were taught using concept mapping approach. Kinechin (2000) suggested that, gender differences can be eliminated when teachers used certain teaching strategies that can bring about gender equity in science education.

This study shows that, Concept mapping strategy promotes students' academic achievement in biology. Students' academic achievement cannot be translated in terms of acquiring knowledge to pass examinations only, but to acquire deep meaningful understanding of the materials presented to the students. Also, the study showed that academic achievement in biology, the increase in students' academic achievement does not depend on the sex of the student, and this means concept mapping is an effective tool for teaching both male and female students.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Overview

This chapter presents a summary of the findings, conclusions made and the recommendations for further studies.

5.1 Summary of the Findings

The summary of the findings emanating from the results of this study is presented based on the research questions as follows.

5.1.1 Effect of concept mapping on student's achievement in biology

The major results obtained from this study based on data analysis reveal that concept mapping method of teaching is very effective in fostering achievement of students in biology. The difference between the mean achievement of students in the pre-intervention test and the post-intervention test was found to be statistically significant ($p < 0.05$) and in favour of the post-intervention test that was taken only after the implementation of the intervention. Hence, concept mapping approach to teaching was found to have a positive influence on the academic achievement of students in biology.

5.1.2 Effect of concept mapping on student's retention ability

The results in this study suggest that concept mapping approach to teaching promotes the ability of students to recall information. The performance of students on the retention test that was administered weeks after the invention was not significantly different ($p > 0.05$) from their performance on the post-intervention test that they took immediately after the intervention. This study concludes, therefore, that concept mapping has a significant influence ($p < 0.05$) on the ability of students to retain information in biology.

5.1.3 Influence of gender on the academic achievement of students taught biology using concept mapping method

This study further revealed that concept mapping has no differential impact on the achievement of male and female students in biology. In the same vein also, there is no significant interaction between gender and instructional method on students' achievement in biology. The male and female students showed no statistically significant difference ($p > 0.05$) between their mean achievements in biology. This study, therefore, concludes that the influence of gender can be ignored when using concept mapping teaching approach to teach biology.

5.2 Conclusion

This study was conducted to assess the effectiveness of concept mapping method on biology students' performance in biology; photosynthesis, cellular respiration, and transport concepts. The finding of this study indicated that concept mapping is very effective in promoting students' understanding and learning of biology concepts and reinforced the ability of students to retain what they have learnt during intervention. Based on the results from the data analysis, the following conclusions were drawn:

- Concept mapping approach to teaching effectively improved the academic performance of both male and female students similarly.
- Concept mapping promotes the ability of students to recall information in biology.
- The sex of students has no influence on their academic achievement when they are taught biology using concept mapping approach.

- Concept mapping can be used to improve male and female students' comprehension of biology concepts.

5.3 Recommendations

The following are some recommendations that were made based on the findings of this study.

- It is evident that, concept mapping approach to teaching is effective in promoting meaningful learning and improving students' academic achievement in biology. Therefore, teachers should use this teaching method to teach biology lessons.
- Workshops should be organised for teachers in the area of concept mapping so that they can embrace the skills of concept mapping teaching method.
- Pre-service biology teachers should be exposed to the concept mapping teaching method
- Concept mapping teaching method should be suggested for some biology content areas in the biology syllabus.
- Curriculum developers may incorporate this strategy in curriculum guidelines for achievement of intended learning outcomes and content development for meaningful and higher order learning.

5.4 Suggestions for Further Studies

- This study was carried out in biology at the senior high school level and it proved concept mapping as a beneficial teaching and learning strategy for cognitive development of students. It is suggested that similar studies be conducted at different levels of education and in different content areas.

- A qualitative or quantitative research is recommended for the exploration of those characteristics of concept mapping approach to teaching that makes it a suitable method for both males and females.
- It is suggested that a study be conducted to assess the differential impact of concept mapping on the academic achievements of low ability and high ability learners.

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APPENDICES

APPENDIX A: PRE TEST

UNIVERSITY OF EDUCATION, WINNEBA

DEPARTMENT OF SCIENCE EDUCATION

PRETEST DATA COLLECTING INSTRUMENT- STUDENT'S KNOWLEDGE OF PHOTOSYNTHESIS TEST (SKPT)

Name of participant…………………………………………………..….

Gender of participant……………………………………………………..….

Class of participant……………………………………………………….….

School of participant……………………………………………………..….

Questions are grouped in three (3) sections, namely sections, A, B and C.

GENERAL INSTRUCTIONS: this contains twenty (20) questions grouped in three (3) sections, namely sections A, B and C please answer ALL the questions in ALL three (3) sections of the test.

SECTION A

MULTIPLE CHOICE QUESTIONS

INSTRUCTIONS: the following questions are following four (4) options lettered A to D.

Find out the correct option and circle A, B, C or indicate your answer

1. The net reaction for photosynthesis produces

a. Water and carbon dioxide

b. Water and oxygen

c. Carbohydrate and carbon dioxide

d. Carbohydrate and oxygen

2. As far as the light reaction of photosynthesis is concerned, what is the role of oxygen

a) It is necessary reactant

b) It is a waste product

c) It is a product that is then utilized in the dark reaction

d) It is not involved as a product or a reactant

3. The essential initial role of light in initiating the light reaction of photosynthesis is to produce

a) Free neutrons

b) Free electrons

c) Free oxygen

d) Free energy in the form of ATP

4. The main purpose of the dark reaction of photosynthesis is the production of

a) Oxygen

b) $NADP^+$

c) Carbohydrate

d) Carbon dioxide

5. The function of water in photosynthesis is to

a. Combine with carbon dioxide

b. Supply electrons in the light-dependent reaction

c. Transport H^+ ions in the light-independent (dark) reactions.

d. Provide molecular oxygen for the light –independent (dark) reactions.

6. All the following statements are correct regarding the light-independent (dark) reactions of photosynthesis except

a) The energy sources unitized is the ATP and NADPH obtained through the light reaction
b) The reaction begins soon after sundown and ends before sun rise
c) The five carbon sugar is constantly being regenerated
d) One of end products is PGAL

7. Which of these statements about photosynthesis is FALSE?

a) Photosynthesis is initiated by the absorption of light energy by chlorophyll molecules
b) the chlorophyll molecules of illuminated chloroplast are raised to a higher energy level
c) the biochemical activities of the light reaction occur in the granae
d) some of the energy of the excited electrons is used to split carbon dioxide into carbon and oxygen

8. Which of these statements concerning chloroplast is **FALSE?**

    a) they make some amounts of ATP to drive some of the photosynthesis process
    b) they have DNA separate from nucleic DNA
    c) they contain granae
    d) They have a fluid matrix called stromal

9. A well-watered potted green plant is kept in a boringly lighted area for 48 hours. What will most likely occur if the light intensity is then reduced slightly during the next 48 hours?

a. Photosynthesis will stop completely

b. The rate at which nitrogen is used plant will increase

c. The rate at which oxygen is released from the plant will decrease

d. Glucose production inside each plant cell will increase

10. Photophosphorylation involves ATP

a) Photosynthesis during light reaction of photosynthesis

b) Breakdown during the light reaction of photosynthesis

c) Formation during the dark reaction photosynthesis

d) Break during the dark reaction of photosynthesis

SECTION B

TRUE/FALSE QUESTIONS

INSTRUCTIONS: the following statements are either true or false. State whether each of the statement is true of false by circling **True or False** to indicate your answer.

1. Both NADP and ATP molecules are formed in the light stage of photosynthesis. **True or False**
2. The palatable mesophyll cells possess more chloroplast and smaller inter-cellular are spaces between them than the spongy mesophyll cells. **True or False**
3. Photosynthesis plays an important role in both carbon dioxide and oxygen cycles in the environment**. True or False**
4. Possession of network of veins adapts the leaf for the process of photosynthesis. **True or False**
5. The palisade mesophyll cell differs from the sponge mesophyll cell in the same paint the possession of a thicker. **True or False**

SECTION C

ESSAY QUESTION

INSTRUCTION: Answer ALL questions in this section

1. Briefly define what you understand by the process of photosynthesis
2. Mention two (2) events which take place during the dark stage of photosynthesis
3. Which substance is tested for to determine that photosynthesis has taken place in a leaf?
4. Which chemical test is usually carried out to test for the substance in (i) above
5. Briefly mention two (2) things that happen to the chlorophyll molecules when it absorbs light energy
6. Mention three (3) factors that affect the rate of photosynthesis is plants.

APPENDIX B: POST TEST

UNIVERSITY OF EDUCATION, WINNEBA

DEPARTMENT OF SCIENCE EDUCATION

Posttest data collecting instrument-student' - students' knowledge of photosynthesis test (SKPT)

Name of participant…………………

Gender of participant………………… Class of participant: ……………………….

School of participant…………………………………………………….

Questions are grouped in three (3) sections, namely sections, A, B and C

SECTION A

MULTIPLE CHOICE QUESTIONS

Instructions: the following question are followed by four (4) options lettered A to D

Find out the correct option and circle A, B, C or D to indicate your answer

1. Which reactions are involved in the process of photosynthesis?

a) Photochemical reaction, only

b) Carbon-fixation reactions, only

c) Both photochemical and carbon-fixation reactions

d) Neither photochemical nor carbon fixation reactions

2. An inorganic molecule required by green plants for the process of photosynthesis is

a) Oxygen molecule

b) Starch

c) Starch carbon dioxide

d) Glucose

3. Which of the following activities occurs in the process of photosynthesis?

a) Chemical energy from organic molecules is converted in to light energy

b) Organic molecules are obtained from the environment

c) Organic molecules are converted inorganic foods molecules

d) Light energy is converted into chemical energy of organic molecules

4. The stacks of flattened membranous sacks in the chloroplast containing chlorophyll are called?

a) Granae

b) Lamellae

c) Cristae

d) Membranes

5. The oxygen given out during photosynthesis s comes out from

a) The breakdown of carbon dioxide

b) The breakdown of water

c) Surplus oxygen taken into the plant

d) The combination of carbon dioxide and water

6. What biological process is described by the equation below?

$$2H_2O \xrightarrow{\text{Light}} 4H^+ O_2 + 4e^-$$

a) Photosynthesis of water

b) Dehydration of water

c) Oxygen synthesis form water

d) Electron product from water

7. Which of the following process does NOT occur in the Calvin cycle?

a) Production of glyceraldehyde 3- phosphate

b) Formation of $NADPH^{+}$

c) Formation of pyruvic acid

d) Utilization of carbon dioxide

8. The light stage of photosynthesis involves

a) Fixation of carbon dioxide

b) The reduction of ribulose diphosphate

c) The breakdown of water

d) Oxidation of $NADP^{+}$ to NADP

9. A plant with pink leaves and stem is capable to photosynthesizing because it

a) Has special cells which can photosynthesize

b) Has chlorophyII which has been masked

c) Uses the pink pigment of photosynthesize

d) Process carotene which is efficient in photosynthesizing

10. Which of the following cells of the leaf lack chloroplast?

a) Guard cells

b) Ordinary epidermal cells

c) Palisade mesophyll cells

d) Spongy mesophyll cells

SECTION B

TRUE/FALSE QUESTIONS

INSTRUCTIONS: the following statements are either true or false. State whether each of the statement is true of false by circling **True or False** to indicate your answer.

The importance of photosynthesis of life include serving as a direct sources of food for secondary consumer. **True or False**

Chloroplast can photosynthesize mainly because they contain the enzymes for the light stage of photosynthesis. **True or False**

The first reaction of the light stage of photosynthesis is photolysis of water. **True or False**

The wavelengths of light in which the rate of photosynthesis is greatest are red and blue. **True or False**

The possession of numerous stomata is a feature that adopts the leaf for photosynthesis **True or False**

SECTION C

ESSAY QUESTIONS

INSTRUCTION: answer all question in this section

1. Mention two (2) events that occur in the light stage of photosynthesis?
2. Describe two (2) features of structures of the leaf that adapt it of photosynthesis
3. Describe briefly photosynthesis of water in photosynthesis
4. Mention two (2) substances that are found during the dark stage of photosynthesis

APPENDIX C: PRE-TEST MARKING GUIDE

MARKING GUIDE FOR THE PRE-TEST (SAPT) ITEMS

1. D
2. B
3. B
4. C
5. B
6. B
7. D
8. B
9. C
10. A
11. False
12. True
13. True
14. True
15. False

(Scoring: 1 mark each) sub-total = 15

Photosynthesis is the process by which green plants manufacture their own food (**1 mark**); using simple (inorganic substances like) carbon (iv) oxide and water **(1 mark);** in the presence of sunlight **(1 mark);** producing oxygen as a byproduct **(1 mark**)

Any 3x1=3

17. Events which occur during the dark or light-independent stage of photosynthesis

i. Fixation of carbon (IV) oxide or carbon fixation (catalyzed by rubisco, producing 3 phosphoglycerates ,3PG) (**1 mark)**

ii. Reduction of 3 PGD (to form glcereraldehydes 3-phosphate) **(1 mark)**

iii. Regeneration of (the CO_2 acceptor) ribulose 1,5 bisphosphates, RuBP, (by ATP) **(1 mark)**

Any 2x2=2

18. (i) starch **(1 mark)**

ii. Iodine test **(1 mark)**

19. When the chlorophyll molecule absorbs as a photon (light energy), it may be

i. Excited / activated/has some of its electrons move to higher energy levels to further away from the nucleus (**1 mark)**

ii. Lose elections(S) (to an oxidizing agent and becomes reducing agent which takes part in a redox reaction. (**1 mark)**

iii. Give off some of the absorbed energy as heat and the rest as light energy (or it fluorescence). (**1 mark)** **Any 2x1=2**

20. factors that affect photosynthesis include;

i. Temperature (**1 mark)**

ii. Presence chlorophyll (**1 mark)**

iii. Light intensity (**1 mark)**

iv. Carbon (IV) Oxide concentration (**1 mark)**

v. Presence of water (**1 mark**

APPENDIX D: POST -TEST MARKING GUIDE

MARKING GUIDE FOR THE POST-TEST (SAPT) ITEMS

1. C
2. C
3. D
4. A
5. B
6. A
7. B
8. C
9. B
10. B
11. False
12. True
13. False
14. True
15. True

16. Events which take place during the light stage of photosynthesis:

i. Absorption of a photon or light energy by chlorophyll molecule, (which becomes excited or activated) **(1 mark)**

ii. Release electron (s) **(1 mark)**

iii. Formation of ATP (**1 mark)**

iv. Formation of $NADPH^+$ **(1 mark)**

v. Photolysis of water (**1 mark)**

17. Features of the leaf that adapt it for photosynthesis include;

i. The lamina is broad and flat for maximum absorption of (sun) light **(1 mark)**

ii. The palisade mesophyll concentrates chlorophyll chloroplast in the upper surface of the leaf for maximum absorption (sun) light (**1 mark)**

iii. The transparent cuticle allows light to reach all parts of the leaf **(1 mark)**

iv. The transparent epidermis allows the light to reach the photosynthesis cells **(1 mark)**

v. The tin lamina allows light to reach all parts of the leaf **(1 mark)**

vi. The numerous stomata allow CO_2/gases to diffuse into leaf for photosynthesis **(1 mark)**

vii. The large intercellular spaces in the sponge mesophyll allow CO_2 /gases to circulate freely in the leaf, and diffuse photolysis **(1 mark)**

viii. The network of veins allows water from the stem to reach every part of the leaf for photosynthesis **(1 mark)**

ix. The network of veins transports products of photosynthesis from the leaf **(1 mark)**

x. The mesophyll cells have thin walls which facilities the movement of substances into and out of the cells (**1 mark)**

Any 2x 1=2

Brief description of photolysis

Photosynthesis II/P $_{680/}$ chlorophyll molecule absorbs a photon or light energy and becomes excited or activated **(1 mark)**

The absorbed (light) energy is used to oxidize a molecule of water **(1 mark)**

This produces electrons/protons. (A half molecule of) oxygen. **(1 mark)**

(i) Carbon (iv) oxide; water **(1 mark each)**

Carbon (IV) oxide is absorbed by diffusion **(1 mark**) through the stomata from the atmosphere (**1 mark)** OR

Water is absorbed by osmosis (**1 mark)** through the root (hairs) from the soil. **(1 mark)**

20. Substance formed the dark or light-independent stage of photosynthesis include

ADP **(1 mark)**

NADP **(1 mark)**

Carbohydrate/sugar/Glucose/Triose sugar/3-phosphoglyecerate

(3PG/PGA)- Glyceraldehyde 3-phosphate (G3P/PGAL) starch. **(1 mark)**

Ribulose 1, 5 bisphosphate (RuBP) **(1 mark)**

Any 2 x 1 = 2 sub-total =15

Grand Total = 27

APPENDIX E: DATA COLLECTION AND ANALYSES TECHNIQUE

Research Questions	Sources of Data	Dat Collection Technique	Data Analyses Technique
2. What is the effect of concept mapping teaching method on senior high school students' academic achievement in biology?	Students	Pre and Post Intervention Tests	t-Test, Frequency/Percentage counts
3. What is the effect of concept mapping on senior high school students' ability to recall information?	Students	Post Intervention Test	ANOVA
4. What is the influence of sex on senior high school students' academic achievement when taught biology using concept mapping method of teaching?	Students	Post Intervention Test	t-Test

APPENDIX F: PRE AND POST-INTERVENTION TEST SCORES

Scores	**Frequency (Pre-Intervention)**	**Frequency (Post-Intervention)**
41-50	7	--
51-60	15	--
61-70	19	4
71-80	1	25
81-90	--	13
91-100	--	--
Total	**42**	**42**

APPENDIX G: T-TEST; PAIRED TWO SAMPLE FOR MEANS

	Pre-Test Scores	***Post-Test Scores***
Mean	58.4047619	77.76190476
Variance	63.41753775	25.06387921
Observations	42	42
Df	41	
t Stat	-13.81727574	
P(T<=t) one-tail	2.53932E-17	
t Critical one-tail	1.682878002	

APPENDIX I: ANOVA

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	10569.57143	2	5284.785714	145.6367084	3.68137E-33	3.069894238
Within Groups	4463.357143	123	36.28745645			
Total	**15032.92857**	**125**				

APPENDIX J: TUKEY HSD TEST

Pair	$\bar{x}_1 - \bar{x}_2$	Critical value	Significant at $\alpha = 5\%$?
A & B	19.36	3.43	Yes
A & C	19.50	3.43	Yes
B & C	0.14	3.43	No

APPENDIX K: PRE-INTERVENTION TEST SCORES

Pre-test Scores	Frequency (males)	Frequency (females)
41-50	4	3
51-60	10	5
61-70	8	11
71-80	--	1
81-90	--	--
91-100	--	--
Total	**22**	**20**