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Concept mapping as a pedagogic tool in teaching undergraduate biology in Nigeria

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Abstract

Biology both as a subject at post primary or a course at the undergraduate levels of education is the foundation of all life sciences. While some students find it easy and interesting, others view it as very broad and therefore stressful to read. In order to address both sides of the divide, novel methods are needed to make both the teaching and learning of the discipline easily grasped and welcomed by all. This is the reason why novel pedagogic tools are required to make the subject matter as clear as possible. The idea of concept mapping even though not entirely new in the field of education seems to be the new bride here. With advances in Science and technology, the teaching of biology especially to undergraduates at the tertiary level becomes simpler and more valuable. This current review is an attempt to conscientize all stakeholders on the importance of applying this principle in teaching Biology particularly in breaking topics and concepts down to the level of the student's understanding and appreciation.

Keywords: Biology; Education; Pedagogy; Concept Map; Undergraduates

1. Introduction

Biology is a subject taught not only at the secondary school level but at advanced level to undergraduates who may be offering it as one of their required courses or as a major degree programme. It occupies a unique position in Nigerian post primary and tertiary institutions as it attracts the greatest number of both science oriented and arts – based students. [1], defined biology as a life science that deals with plants and animals, their structure, function, growth and their relationships with the environment. With the knowledge of biology, the students are in a position to understand the structure and functions of different parts of the body, the environment in which they live and how best to conduct themselves [1, 2]. Biology provides a platform for teaching students the ability to apply learned scientific concepts and principles in solving everyday – related problems.

Consequently, the objectives of biology education at senior secondary and more especially at higher education levels are that the students at the end of their study should be able to acquire adequate laboratory, theoretical, and practical skills that are meaningful and relevannt to everyday life in matters of personal and community health, agriculture, and functional scientific attitudes [2]. In accordance with these stated objectives the spiral and conceptual approach was adopted in curriculum planning to teach the subject f Biology, planning the subject and sequencing the course content. In this approach, the concept taught are arranged in such a way that they run throughout the period of the course,

Learner centred knowledge are now the widely accepted form of pedagogical methods which can bring about effective achievement and retention of the above stated objectives. Although, [3] and [4] submitted that no single method is best for the teaching of science and especially biology, they unanimously agreed that method that would involve active

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student participation such as field work, laboratory work, concept mapping, advance organizer and group work and so on would ensure higher performance and retention. Concept maps have been used as assessment tools and curriculum planning tools from thee onset of modern education organisation and planning [4]. Teaching programs that enable students to learn by seeing, living, creating and relating previous knowledge with the new learned knowledge, aims to breed individuals that can reach and research for information and eventually individuals that can produce new information. All these reasons should force our education system to move away from learning through memorizing and replace the system with new concepts in Science and Technology. Concept map is a teaching programme, which aims to grow individuals that question the problems they face and bring solution, also question the environment they live in and how to add value to it. Researches have opined that teaching methodology can improve leaner's retention level. [5] pointed out that using concrete objects in learning leads to better retention information and development of favourable attitude towards science and technology. Similarly, [6] observed that concept mapping instructional strategy promotes knowledge construction, encourage independent thinking and actively foster deeper understanding of ideas or large thinking skills and lead to greater command and ownership of knowledge. In recent times, the application of constructivist learning theory is the most appreciable way of achieving optimal student performance. The constructivist learning has ganered much support in literature ranging from philosophical discussions, testimonial assertions by researchers and educators who have seen constructivism work successful with their students and experimental results showing higher students` performance in constructivist learning environments [6].

Concept maps provide a unique graphical view of how students organize, connect, and synthesize information. As a result, concept mapping offers benefits to both students and teachers. Concept maps give students an opportunity to: think about the connections between the science terms being learned, organize their thoughts and visualize the relationships between key concepts in a systematic way, and reflects on their understanding. In summary concept maps allow students to think deeply about science by helping them to better understand and organize what they learn, and to store and retrieve information more efficiently. This is the objective of this current review.

By and large, effective teaching and learning is achieved through good instructional technique. The notion that learning is influenced by prior experiences and ideas led to the development of what has become the dominant view of learning in science education today- constructivism [5. 6]. Constructivist school of thought concerning learning holds that people construct their own meanings from what they experience, rather than acquiring Knowledge from other avalanche of information. The impact and development of this led to the development of different strategies now employed in the teaching and learning of science. Specific examples among constructivist approaches include concept mapping and cooperative learning/learning cycle. Literature on concept mapping, cooperative learning and learning cycle shows that they all share complimentary objectives of engaging students in the learning process and promoting higher thought processes and more authentic behaviours required for scientific and technological development. It was this finding that gave rise to this present review with the sole purpose of pointing out the effect of concept mapping techniques on students' performance and retention in biology. Over the years, research and curriculum development have shown that effective instruction is much more than the presentation of a concept, process, or skills. The major concern of science education researchers is the identification of the best instructional methods/strategies which will enable all learners to learn effectively especially in our educational system where learning materials are not available. [7] stated that effective classroom appears to be one in which students are active, kept aware of instructional objectives and receive feedback on their progress towards the stated objectives. In classroom where elements of constructivism are incorporated in teaching and learning, students gets opportunities to physically interact with instructional materials and engage in varied kinds of activities. This position therefore, suggests that for effective learning to take place students must be actively involved in the learning process.

The principle of a concept map is that it provides a visual means of showing connections and relationships between a hierarchy of ideas ranging from the very concrete to the abstract [7]. [8] noted that concept maps help in understanding ideas by showing the connections with other ideas. The history of development of concept mapping as an instructional tool can be traced to the early 1970s [8]. Since its introduction, the concept map has become a very useful tool in teaching and learning and particularly in science education research. Literature on concept mapping indicates that it has been used for instruction, assessment and learning at diverse levels of education. Isolated studies from literature on the effects of concept mapping when used as an instructional tool for teaching and learning has shown its relevance in improving the cognitive and affective aspects of the student in question.

The theory of constructivism (knowledge) corresponds to Piaget's theory of adaptation [8]. Adaptation has dual nature – assimilation and accommodation. Assimilation is a form of adaptation through which a child takes in new information, while accommodation has a balancing effect on prior knowledge and the new information and thus, a state of equilibrium is achieved ultimately. Once a state of equilibrium is challenged by new experiences, the equilibrium is disturbed and cognitive conflict surface. This prompts a search for solution until an acceptable explanation is found

which again establishes a new equilibrium. Piaget's work achieved great heights because he was able to demonstrate how children learn in stages and by Interaction with their environment. Thus, knowledge is constructed by the child actively from birth. This brings about constructivism. The mechanism of constructing meaningful learning from within by the learner [9] see constructivism as an epistemology of how people learn. It describes how one attains and develop independent thinking faculty. The same research stated that constructivist epistemology is the production of new knowledge as a human construction. It is therefore the knowledge that is actively constructed by the learner on the ground that learning is a continuous chain of enlargement where the unfamiliar are related to the familiar. The constructivist view of learning has become a leading idea in teaching and learning in recent times. The learner comes into any new situation with prior knowledge that is agreed upon by communities of learners. Thus, learners come into any new situation with prior knowledge based on past experiences. Constructivist theory is the instructional approach which holds the view that, knowledge is personally constructed and reconstructed by the learner on his prior knowledge and experience. However, it must be stated here that there is no single method best for the teaching of science as diverse strategies are needed to obtain maximum result.

2. Conceptual Framework

Amidst all of the research that has been done in the field of education, concept mapping has emerged as the latest success in a series of new teaching strategies. The use of concepts is the most notable method of showing the relationship between concepts. Concept maps are graphical tools for organizing and representing knowledge. They include thoughts, usually enclosed in circles or boxes of some type, and relationships between ideas indicated by a connecting line linking two concepts. Words on the line referred to as linking words or linking phrases and they specify the relationship between any two concepts. They also are diagrams which include concepts that are linked by propositions. They are intended to represent meaningful relationships between concepts in the form of assertions or propositions. According to [10], concept mapping is an example of meta –cognitive strategy of instruction, which involves focusing attention on how the learner learns and the learner's awareness of his cognitive processes as learning progresses. It is believed that the process of drawing a concept map makes the task of revision more active and can be used as a way to encourage peer learning. He noted, that through the use of concept maps, relatively irrelevant subject matters are not been laboured on and the teachers misconceptions are not taught to students as well.

Concept maps were developed in 1972 in the course of Novak's research program at Cornell University where he sought to follow and understand changes in children's knowledge of science [10, 11]. During the course of this study the researchers interviewed many children, and they found it difficult to identify specific changes in the children's understanding of science concepts by examination of interview transcripts. This program was based on the learning psychology of David Ausubel. The fundamental idea in Ausubel's cognitive psychology is that learning takes place by the *assimilation* of new concepts, propositions into existing concept and propositional frameworks held by the learner. This knowledge structure as held by a learner is also referred to as the individual's *cognitive structure*. Out of the necessity to find a better way to represent children's conceptual understanding emerged the idea of representing children's knowledge in the form of a concept map. Thus was born a new tool not only for use in research, but also for many other uses.

The steps in a typical concept mapping include;

Selecting an item for mapping. Choose and underline keywords, phrases, include objects or events in the list. Rank the list of concepts from the most abstract to the most specific.

- Clustering concepts according to two criteria; concept that function at a similar level of abstraction and concept that interrelate closely.
- Arranging the concepts as a two dimensional array analogous to a road map.
- Linking related concepts with lines, and labeling each line in propositional form.

A complete map represents an understanding of the relationship between important sets of concepts and efficiently communicates this understanding to others. Propositions are statements about some object or event in the universe, either naturally occurring or constructed. Propositions contain two or more concepts connected using linking words or phrases to form a meaningful statement. Sometimes these are called semantic units, or units of meaning. Figure 1 shows an example of a concept map that illustrates the above characteristics.

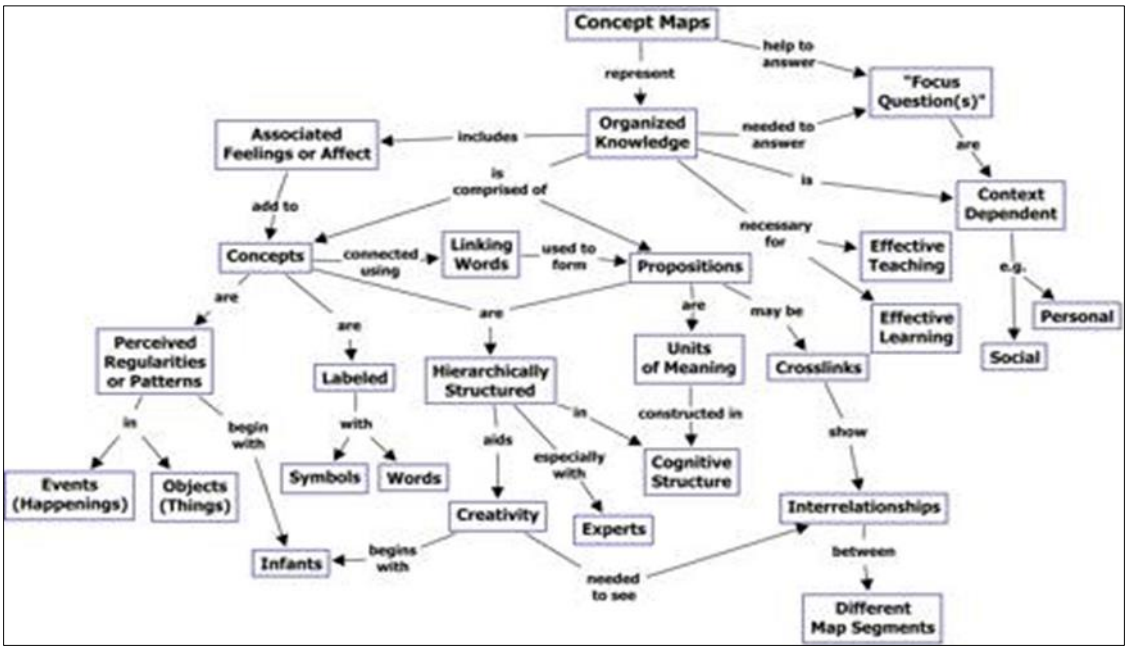

Figure 1 Diagram showing the key features of concept maps. (Source: Danmole, B.T. and Femi-Adeoye, K.O. (2004). Effects of concept mapping technique on senior secondary school students' achievement and retention of ecology concepts)

The characteristic of concept maps is that they are represented in a hierarchical fashion with the most inclusive, most general concepts at the top of the map and the more specific, less general concepts arranged hierarchically below. The hierarchical structure for a particular domain of knowledge also depends on the context in which that knowledge is being applied or considered. Therefore, it is best to construct concept maps with reference to some particular question we seek to answer, which we have called a focus question. The concept map may pertain to some situation or event that we are trying to understand through the organization of knowledge in the form of a concept map, thus providing the context for the concept map. Another important characteristic of concept maps is the inclusion of *cross-links*. These are relationships or links between concepts in different segments or domains of the concept map. Cross-links help shows how a concept in one domain of knowledge represented on the map is related to a concept in another domain shown on the map. In the creation of new knowledge, cross-links often represent creative leaps on the part of the knowledge producer. Researchers have found out that concept maps should be recommended as a means of producing meaningful learning in the analysis of scientific articles as well as enhancing the Integration of theory and practice and is also made an effective means of bridging the gap between conception and procedural knowledge[12]. The connections that concept maps brings not only allow students to draw associations amongst the main concepts being presented, but also generate greater retention, application and understanding. As a flexible tool, it can be applied in a variety of context to improve the quality of learning. Thus, the following are the advantages of the use of concept maps among others:

To facilitate meaningful learning by providing a means for students to draw together the concepts they have learned in a resourceful and integral manner.

- As an evaluation tool.
- They make the task of revision less boring and exciting to students.
- They help students to have the picture of the whole topic on one page.
- They discourage students from including irrelevances in their notes.
- They encourage brevity in notes and concentration on relationships that exist between concepts covered in a text or lecture, and the hierarchy of those concepts.
- They allow students to play and practise more with concepts which leads to more understanding of the concepts and the relationships that exist among them.
- The connections that concept maps facilitate not only allow students to draw associations amongst the main concepts being presented, but also generate greater retention, application and understanding.
- Concept maps are effective for affective, as well as cognitive instructional objectives. They suggest that concept mapping strategy significantly reduce anxiety towards biology achievement in males.

- It confers on learners the ability to control, determine and make decisions about 'the law' and pace of what is learned on the learner the advantage of shaking free from the pressures which would otherwise impede meaningful learning.

Concept maps can be used as a teaching tool to transmit information about concepts to students or help students to construct an understanding of their subject or courses. It provides a vehicle for introducing new concepts and connecting them to one another and to known concepts, encourages active construction of concepts, fosters metacognitive knowledge and autonomy, motivates conjunctive making and guesses, underscores personal interpretation, provides an opportunity to engage in logical reasoning; prompts problem solving; kindles dialogue and a perception of biological knowledge as a scientific process and promotes a view of knowledge as dynamic idea.

2.1 A Concept Map

As indicated earlier, a concept map was *perceived as a regularity (or pattern) in events or objects, or records of events or objects, designated by label.* It is generally recognized now that the meaningful learning processes described are the same processes used by scientists Biologists and Mathematicians, or experts in any discipline, to construct new knowledge. [12] has argued that new *knowledge creation* is nothing more than a relatively high level of meaningful learning accomplished by individuals who have a well-organized knowledge structure in the particular field of study, and also a strong emotional commitment to persist in finding new meanings. Learners struggling to create good concept maps are themselves engaged in a creative process, and this can be challenging, especially to learners who have spent most of their life learning by rote. Rote learning contributes very little at best to our knowledge structures, and therefore cannot underlie creative or constructive thinking or novel problem solving. Out of the necessity to find a better way to represent children's conceptual understanding emerged the idea of representing children's knowledge in the form of a concept map. This knowledge structure as held by a learner is also referred to as the individual's cognitive structure. According to Novak the following types of concept map have been identified

- Spider – organised by placing the central theme or general concept in the centre of the map. Outreaching specific concept surround the center of the map like a web.
- Hierarchy – present information in a descending order of importance. The most general concept is place on top.
- Flow chart – organizes information in a linear format connected by cross links.
- System – organizes information in a format which is similar to flow chart with the addition of input and outputs.

2.2 Concept of Biology

Biology is a natural science concerned with the study of life and living organisms, including their structure, function, growth, evolution, distribution, and taxonomy [13]. Modern biology is a vast and eclectic field, composed of many branches and sub disciplines. However, despite the broad scope of biology, there are certain general and unifying concepts within it that govern all study and research, consolidating it into single, coherent field. In general, biology recognizes the cell as the basic unit of life, genes as the basic unit of heredity, and evolution as the engine that propels the synthesis and creation of new species. It is also understood today that all organisms survive by consuming and transforming energy and by regulating their internal environment to maintain a stable and vital condition [13]. Biology learning includes understanding biological organization from molecules to ecosystems. Although learning and teaching biology begins at elementary grades, under other titles of primary science or integrated science, they begin to assume more meaning at the senior secondary school level. Biology teaching and learning include many factors which are determinants of leaning quality which can be classified as learning cognitive factor and affective factors. For the cognitive domain, reasoning ability, information processing and academic achievements are among the most studied constructs or factors. While the affective domain in science and biology education in particular are attitudes, self-efficacy, anxiety, and motivation [14]. Figures. 2 and 3 show the concept of ecology and photosynthesis (some topics one usually encounter in Biology courses) with the aid of concept map.

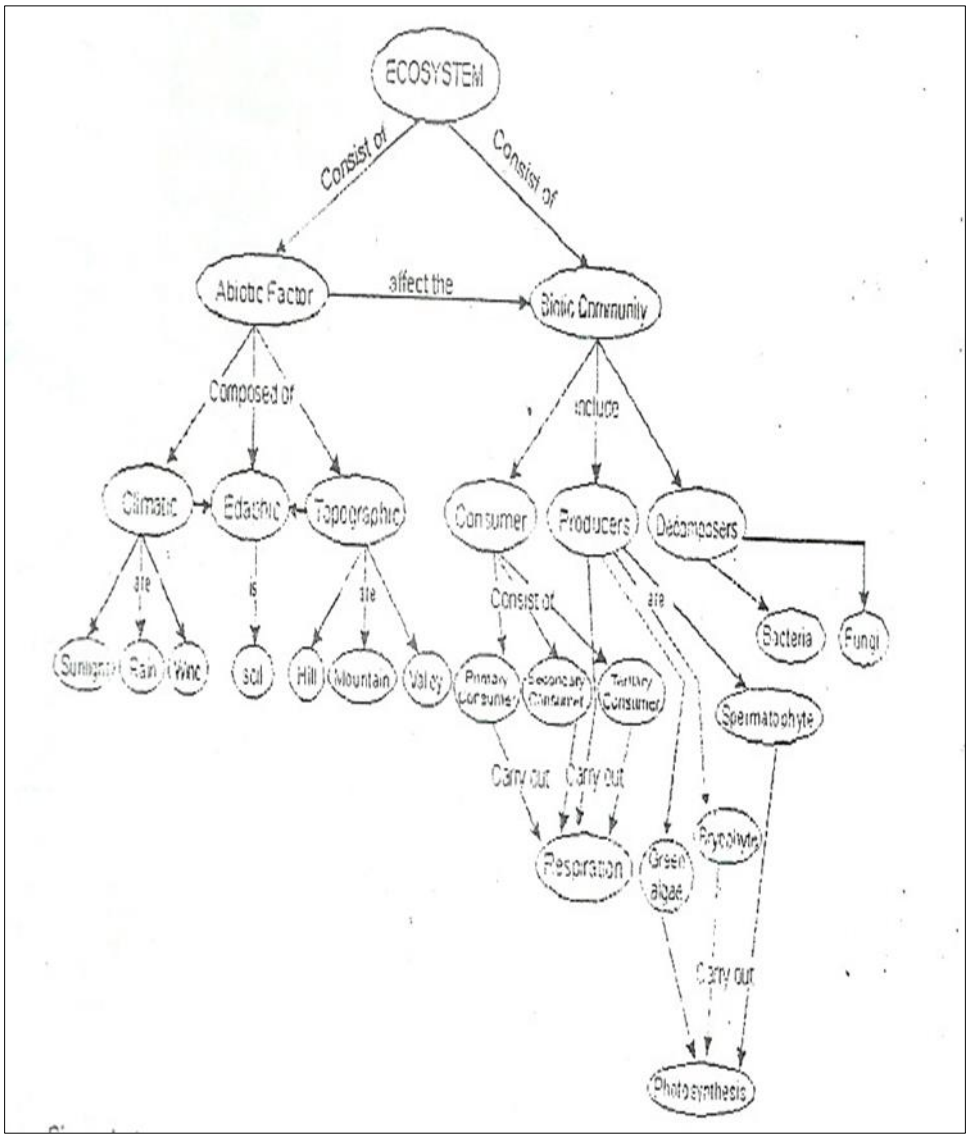

Figure 2 Typical concept Map in teaching Ecology

2.3 Concept of Performance

In any educational institution, success is measured by the level of academic performance exhibited by the student. As career competition grows ever fiercer in the working world; the importance of academic performance has caught the attention of parents, the society, government and educational institutions. Poor academic performance of students in biology as a science subject in secondary schools and at undergraduate levels has been linked to poor teaching technique, un-equipped laboratories, lack of instructional materials and so many factors too numerous to mention. The challenge of students' under-achievement in biology has been attributed largely to apathy and simpler ways of explaining concepts by instructors. This is also connected to absence of instructional strategies used in teaching and when compared to other science courses like mathematics, it was observed that a learner centred approach was not adopted. Therefore, the emphasis should be on student based teaching technique in order to promote effective learning.

2.4 Aims of Concept Mapping

Concept mapping ensures meaningful learning, which is not the extent of how much the teacher tries to furnish the learners with what they 'do not know' but that the learners are engaged in an active continuous process of cognitive structure construction. Concept map provides a variety of features that make it possible for teachers to use concept maps for a variety of the tasks that students perform in the classroom.

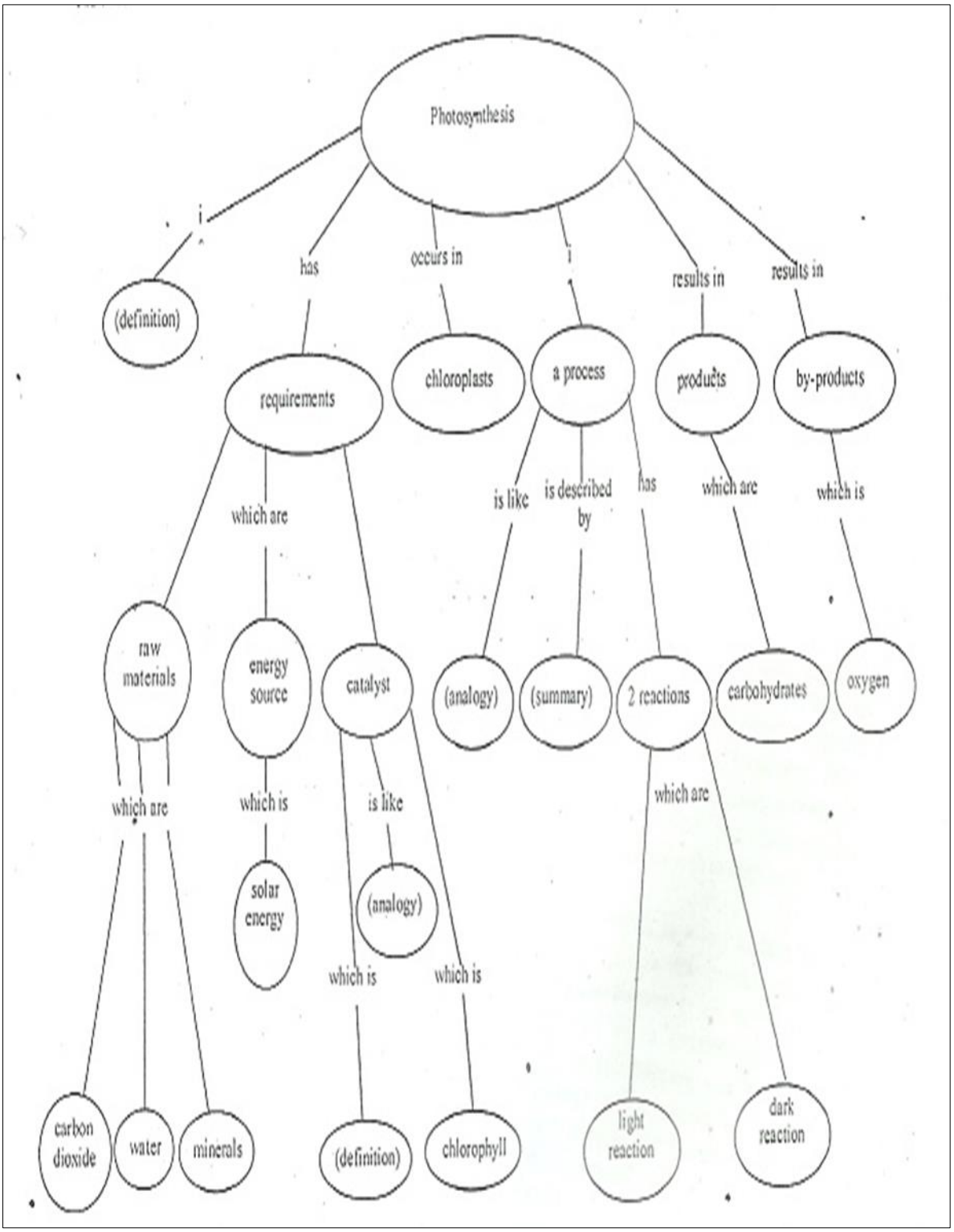

Figure 3 Typical concept map in teaching Photosynthesis

2.5 Implications of Concept mapping in curriculum planning

In curriculum planning, concept maps can be enormously useful. They present in a highly concise manner the key concepts and principles to be taught. The hierarchical organization of concept maps suggests more optimal sequencing of instructional material. Since the fundamental characteristic of meaningful learning is integration of new knowledge with the learners' previous concept and propositional frameworks, proceeding from the more general, more inclusive concepts to the more specific information which usually serves to encourage and enhance meaningful learning. Thus, in

curriculum planning, there is need to construct a global "macro map" showing the major ideas we plan to present in a course for instance, or in a whole curriculum, and also more specific "micro maps" to show the knowledge structure for a very specific segment of the instructional program. Using concept maps in planning a curriculum or instruction on a specific topic helps to make the instruction "conceptually transparent" to students. Many students have difficulty identifying the important concepts in a text, lecture or other form of presentation. Part of the problem stems from a pattern of learning that simply requires memorization of information, and no evaluation of the information is required. Such students fail to construct powerful concept and propositional frameworks, leading them to see learning as a blur of myriad facts, dates, names, equations, or procedural rules to be memorized. For these students, the subject matter of most disciplines, and especially science, mathematics, and history, is a cacophony of information to memorize, and they usually find this boring. Many feel they cannot master knowledge in the field. If concept maps are used in planning instruction and students are required to construct concept maps as they are learning, previously unsuccessful students can become successful in making sense out of science and any other discipline, acquiring a feeling of control over the subject matter [17]. Below are some of the merits of applying concept maps in teaching courses like Biology to students and teachers alike at the tertiary level:

Learning tool – Students uses concept map for note taking, study tool, collaborative mapping and summarizing reading.

It was shown that when student work collaboratively online with concept maps, learning increases.

- Evaluation tool – When concept maps are used in instruction, they can also be used for evaluation. There is nothing written in stone that says multiple choice tests must be used from grade school through university, and perhaps in time even national achievement exams will utilize concept mapping as a powerful evaluation tool. This is a chicken-and-egg problem because concept maps cannot be required on national achievement tests if most students have not been given opportunities to learn to use this knowledge representation tool. On the other hand, if state, regional, and national exams would begin to include concept maps as a segment of the exam, there would be a great incentive for teachers to teach students how to use this tool. Hopefully, in the next two decades, this will come to pass. Currently there are a number of projects in the USA and elsewhere that are doing research to see if better evaluation tools can be developed, including the use of concept maps. We should begin to see significant advances in this area in the next several years.
- Assessment tool – Students achievement can be tested or examined by concept mapping.
- Reinforce understanding – using concept maps reinforce students understanding and learning. It encourages students to use meaningful mode learning patterns.
- Teaching tool- Concept map help the teacher to convey a clearer picture of the topics and their relationship to the students. It is used as an advance organizer in teaching.
- Planning too – It is used to plan and evaluate curricula, plan lesson preparation, lecture notes, lessons evaluation, and so forth.
- Reviewing for an Exam: Concept mapping can be a productive way to study for an exam, particularly if the emphasis of the course is on understanding and applying abstract, theoretical material rather than on simply reproducing memorized information. An effective use of concept map will help aims and objectives of a curriculum to be achieve at every lesson sessions.

3. Impact of Concept Mapping Strategy on Students Performance in Biology

Research in education has shown many changes in the modes of instruction, notable among these were expository, discovery, laboratory work, field trip, and other methods. These various methods have always been applied traditionally where teachers are active and the learners are passive listeners with little or no participation. It is best known and practiced widely by most teachers [18]. The traditional main objectives is get as large body of Information as possible to a large grand of learners in the shortest possible time with minimum costs. Due to poor teaching facilities and large classes, most teachers use this as escape route in most institutions. The advice is that teaching strategies should be such that they facilitate conceptual change in learners psyche. Although no single method is best for the teaching of science and especially biology, it is unanimously agreed that methods that would involve activities of students participation like group work, concept mapping and so forth, ensure high performance in majority of cases. Therefore, the desire to improve science students' performance through more effective instructional strategy is very imperative. [19] Defined learning as a relatively enduring change in behaviour, which is a function of prior behaviour usually called practice. Learning involves knowledge, ideas, skills, values and experiences. Therefore, learning is said to have taken place if what is learned is retained. The basis for retention is the memory. Thus [20] describe retention as storage of learning over some period of time, termed retention interval, which involves getting responses out of storage. He also stated that a student does better when he learns through his own effort. The teacher puts student in a position of self – learning and

exploring the approach to learning that makes learning functional. Thus, things learned through this process can then be effectively transferred to real life situation. It is therefore pertinent that students engage in collaborative small group activity associated with concept mapping; to explore the relationship between individual learning and group development. Concept map provides a vehicle for introducing new concepts and connecting them to one another and to key concepts.

4. Conclusion

Teaching of Biology at any level of education in Nigeria will not be effective without making deliberate effort to simplify some of the concepts to the learners. One advantage the field has over some basic sciences is that it can easily be related to what is happening within the body of man and his environment. Be that as it may, the use of concept note makes it much more understandable and acceptable by students. Pedagogical re-appraisal of the course is therefore needed now than ever before considering the role Biology plays as a bedrock of all life sciences.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest.

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