

## **Which strategy best suits biology teaching? Lecturing, concept mapping, cooperative learning or learning cycle?**

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### Abstract

The purpose of this study was to compare the achievement of students taught with concept mapping, cooperative learning, 5E learning cycle and lecture methods with the intention of identifying which one among them could be most suitable for teaching Biology. To guide this study, four research questions were raised and tested at 0.05 level of significance. The design of the study was pre-test, post-test, delayed post-test, quasi experimental repeated measures design. The samples of the study consisted of four mixed secondary schools, 259 students and eight Biology teachers. The major findings of the study include: significant effect of the four instructional methods on achievement and retention; students in the 5E learning cycle and cooperative learning groups significantly outscored those in the concept mapping and lecture groups on achievement and retention tests; students in concept mapping outscored those in lecture group both on immediate achievement and retention tests; students in 5E learning cycle and cooperative learning groups did not significantly differ on achievement and retention tests; males and females in all the four groups did not significantly differ on the achievement tests; and a non-significant interaction effect between sex and method of instruction on achievement. It was concluded that the adoption of either 5E learning cycle or cooperative learning strategies may be appropriate for the teaching and learning of Biology.

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### Introduction

“Since 2000, study after study has made it clear that there is an alarming crisis in relation to students’ interest in science, either as a possible future career, or as an intrinsic interest that will continue after school” (Fensham, 2008, p. 20). In the UK in the late 1960s, the publication of the Dainton report (Department of Education Science (DES), 1968) which examined the flow of candidates in science and technology into higher education documented a swing from science in the school-age population as a whole. The list of countries experiencing declining interest of students in science is on the increase particularly among the developed countries (Fensham, 2008). One factor which has contributed to low interest in science by students is the method adopted for teaching and learning science. Fensham (2008, p. 20-21) listed four views of students which contribute directly to low interest in science:

- (i) Science teaching is predominantly transmissive,
- (ii) The content of school science has an abstractness that makes it irrelevant,
- (iii) Learning science is relatively difficult, for both successful and unsuccessful students,

and (iv) Hence, it is not surprising that many students in considering the senior secondary years are saying: Why should I continue studying science subjects when there are more interactive, interesting and less difficult ones to study?

This unhealthy development in the disposition of students towards science has sparked the search for and development of alternative methods of science teaching and learning which can stimulate students' interest and guarantee an educational system that offers equal opportunities for all sexes. Science education as a field of study is therefore in dire need of methods with qualities such as lesson clarity, promotion of self-activity, promotion of self-development, stimulation of interest and curiosity and relying on the psychological process of teaching and learning to recommend to science teachers. The methods should encourage science teaching and learning that is better than it is now.

Many students today are learning science in a passive way in classrooms where information is organized and presented to them by their teacher (Moyer, Hackett & Everett, 2007). They noted that "often, the teacher pays little attention to what students already know about science. In this learning model, the information transmitted by the teacher and curriculum materials are assumed to make sense and seem reasonable to the students" (p.4). This model views science from a limited perspective. Science, seen in this way, has been influenced by the manner in which it is taught and studied. With this conception, science is thus viewed as a collection of organized body of information about the natural world. However, another view of science is the dynamic interaction of thought processes, skills and attitudes that help learners develop a richer understanding of the natural world and its impact on society. Moyer et al (2007, p.4) pointed out that "science viewed in this way, sees science as not just a body of knowledge but rather a process for producing knowledge". This latter view of science therefore calls for a change from the transmission method of presenting science to students to allowing the students to interact with the natural world to create knowledge.

Arising from the view of science as a process for generating knowledge, major reform efforts were carried out in science education in the 1990s and culminated in the development of the National Science Education Standards (NSES) (NRC, 1996) in the U.S. The content standards presented in the National Standards elaborate what students should understand and able to do in natural science, and the personal and social context that should be considered in the design of science curriculum. Trowbridge & Bybee (1996, p. 113) stated that "these standards emphasize inquiry-oriented activities, connections between science and technology, the history and nature of science as students develop an understanding of fundamental ideas and abilities in science, and a vision of good science teaching model. The NSES, although recommended for the U.S educational system, are internationally practiced in science education. Trowbridge and Bybee (1996) noted that the standards encourage all students – including members of populations defined by race, ethnicity, economic status, gender, and physical and intellectual capacity - to study science throughout their school years and to pursue career in science. The NSES emphasize that the learning of science is an active process. Learning science is something that students do, not something that is done for them. They further stated that doing science requires students to be involved in both physical and mental processes, collectively known as scientific inquiry. Scientific inquiry requires both hands-on activities and minds-on as well.

Knowledge, which is long lasting and available for use later, is created through the transmission of experience. The expansion of education, creation of new fields of discipline and development of different instructional approaches, calls for detailed assessment of instructional strategies before they are selected to use in science classroom. Also with the increasing emphasis on lesson clarity, promotion of self-activity, stimulation of interest and curiosity, teaching methods associated with subject matter disciplines, instructional variety, retention rates and life-long learning, there is good reason to explore other instructional approaches for teaching science different from the one predominantly used (lecture) for very long time. This exploration is to determine if the methods have varying effects on students' achievement when compared with the lifelong objectives of teaching science. This indeed formed the rationale for the current study of determining the effects of concept mapping, cooperative learning, 5E learning cycle and lecture instructional strategies on students' achievement and retention of biological knowledge when used for instruction.

### Reviewed Related Literature

Generally, there are several perspectives that address ways in which pupils learn (Bennett, 2003). Four perspectives which have been suggested to particularly influence science education are: transmission of knowledge; discovery learning; developmental view of learning; and constructivism. These are based on different theoretical models of leaning and are outlined below.

#### Four Theories of Learning

##### *Transmission Method (Traditional Method)*

The transmission view of teaching and learning sees teachers as passing over their knowledge to their pupils (Bennett, 2003; Borich, 2004; Trowbridge & Bybee, 1996; Trowbridge, Bybee & Powell, 2000). This view is strongly linked to expository teaching; teachers standing at the front telling their pupils about scientific ideas. The transmission view implies that the pupil's role in the learning process is largely passive, and that a pupil's mind is a tabula rasa- a blank state onto which knowledge can be written. The lecture or traditional teaching method has the following advantages:

1. It is easy to create interest in a topic or subject by the teacher.
2. Students easily acquire knowledge, new information, and explanation of events or things.
3. It helps students to clarify and gain better understanding of a subject, topic, matter or event.
4. Students and teachers cover more content materials within a short period of time.

The major limitation of this method is that there is relatively little student activity and involvement (Ajaja, 2009; Bennett, 2003; Borich, 2004; Trowbridge & Bybee, 1996; Trowbridge et al; 2000). Thus, the students are said to be passive .The limitation experienced with the transmission approach led to the development of other views of science teaching and learning.

##### *Discovery Method*

Discovering learning involves presenting pupils with information in a form which requires them to discern relationships within the information and to structure and make sense of the information and relationship. This form of self-directed learning could promote higher forms of thinking with the aid of meta-cognitive strategies (Borich, 2004). Discovery learning

sees pupils as having a much more active role in their learning. Proponents of this approach argue that the enhanced learning by learners is due to their active participation in learning process.

The use of discovery approach for teaching and learning has been associated with science education for over one hundred years now (Trowbridge & Bybee, 1996; Trowbridge et al, 2000). Ajaja (1998) and Bennett (2003) noted that the school science curricula like Biological Science Curriculum Study (BSCS) (American Institute of Biological Sciences, 1958), Chemical Education Material Study (CEMS) (Campbell, 1961) and Chemical Bond Approach (CBA) (Strong, 1968) which adopted the discovery approach to teaching emphasized the presentation of science to pupils as a way in which they could conduct their own inquiries into the nature of things. Discovery learning in science places a strong emphasis on practical work organized in such a way that pupils make observations, look for patterns, and come up with possible explanation for those patterns.

The discovery method, unlike the lecture method, has the following advantages:

1. It helps the pupil understand the material better by showing him that the concepts involved are so reasonable that he can discover them himself or herself.
2. It helps a learner to remember concepts, principles and laws better since what is discovered is by far less likely to be forgotten.
3. It helps the individual to learn on his own so that he or she may become increasingly independent of the teacher.
4. It keeps the teacher in touch with his or her class so that he or she knows whether the pupils understand or follow the work.

After a long use of discovery approach for teaching and learning of science, it became apparent that there were limitations with the approach. Bennett (2003) reported that questions were asked about the appropriateness of asking pupils to “discover” things for themselves when both teachers and pupils knew that the answers were already there in the form of currently accepted scientific theories. There was also a question over the nature of the understanding pupils developed when left to their own devices and to what extent pupils “discover” the scientifically accepted explanations of the phenomena they experience. These identified limitations and criticisms levied against discovery learning, paved the way for a shift in research efforts from discovery learning to constructivism.

#### *Developmental views of learning*

Research work in the field of psychology of education has examined how children’s abilities to obtain, process and use information develop as they grow and mature. Bennett (2003) noted that the single most influential theory of cognitive development in the twentieth century emerged from the work of Jean Piaget. His theory describes four stages of intellectual development through which children pass:

- (i) Sensory-motor stage (0-2years) Children learn through their senses and physical experiences.
- (ii) Pre-operational stage (2-7years) Children reason directly from what they perceive and may not be logical.
- (iii) Concrete operational stage (7-11years) Thinking characterized by logic and does not require real objectives at hand.
- (iv) Formal operational stage; (11years and above) Children become capable of abstract thought.

Two key processes in learning are central to Piaget's theory. Piaget viewed learning as an active process in which the learner compares and contrasts modes of thinking about new experiences with those of prior experiences. Moyer et al (2007) noted that often the child realizes that the explanation used for an earlier experience does not fit with a new experience. This is resolved by the learner having to modify his/her way of thinking to come to a conclusion that seems personally reasonable Piaget called this, process of thought adjustment equilibration (Piaget & Inhelder, 1958). This adaptation occurs through the two active thought processes, assimilation and accommodation.

### *Constructivism*

Cognitive psychologists and science educators influenced by the early work of Ausubel (1968), Bruner (1960), Kelly (1955) and Vygotsky (1978) are of the view that useful knowledge is not passed along intact from one person to another, nor is it discovered in the external world. The synthesis of the ideas generated from these theorists gave rise to the constructivist perspective. The constructivist insists that knowledge is produced by the learner (Bennett, 2003, Moyer et al, 2007, Trowbridge & Bybee, 1996). Underlying the constructivist perspective is the notion that all people normally try to make sense of their world. Through their own constructive processes, individuals impose order and predictability on phenomena and events of the world. Trowbridge and Bybee (1996) stressed that the constructivists contend that we cannot directly teach a student the principles of science.

### Three Instructional Strategies

The notion that learning is influenced by prior experiences and must be constructed by the learner led to the development of what has become the dominant view of learning in science education today (Bennett, 2003; Trowbridge & Bybee, 1996; Trowbridge et al, 2000). The impact and influence of this view of learning gave rise to the development of new strategies of teaching science such as concept mapping, cooperative learning and learning cycle where the emphasis is on the active participation of learners in the learning process.

All three instructional strategies share complimentary objectives of engaging students in the learning process and promoting higher thought processes and more authentic behaviors required for scientific and technological development. Wise and Okey (1983) stated that effective science 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 get opportunities to physically interact with instructional materials and engage in varied kinds of activities. This position suggests that for effective learning to take place, students must be actively involved in the learning process. The three instructional strategies which employed the principles of constructivism are discussed below.

### *Concept Mapping*

A concept map is a two-dimensional representation of the relationship between key ideas. At first glance, a concept map looks like a flow chart in which key terms are placed in boxes connected by directional arrows. When based on educational psychology theories of how we organize information, concept maps are hierarchical, with broader, more general items at the top and more specific topics arranged in a cascade below them. According to Novak and Gowin (1984), a standard concept map construction methods include the following series of steps:

- (i.) define the topic,

- (ii.) list the most important concepts;
- (iii.) arrange concepts hierarchically;
- (iv.) add links to form a preliminary concept map;
- (v.) add linking phrases;
- (vi.) add cross links; and
- (vii.) review map.

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 (Ajaja, 2009; Bennett, 2003). Ajaja (2011) noted that concept maps help in understanding ideas by showing the connections with other ideas.

The benefits of concept mapping are mainly to the individual making the map. The process of simplifying concepts and arranging them on a page forces the learner to think about what is most important. It helps to clarify one's thought and understanding and makes learning more meaningful. A concept map can be a heuristic device that is a process in which the learner can make discoveries and uncover meanings through trial and error. It helps in the development of critical thinking skills which is a conscious effort to think about thinking.

Ajaja (2011) stated that the development of concept mapping as an instructional tool can be traced to the early work of Ausubel and others in the 1970s. Continuing, Ajaja noted that since its introduction, concept mapping has become a very useful tool in teaching and learning and particularly in science education. Literature on concept mapping indicates that it has been used for instruction, assessment and learning (Johnson & Raven, 1998; Novak & Musonda, 1991; Power & Wright, 1992; Trowbridge & Bybee, 1996; Trowbridge, Bybee & Powell, 2000).

Some studies on the effects of concept mapping when used as an instructional tool for teaching and learning, indicated its relevance in improving the cognitive and affective aspects of learning. A study conducted by Ajaja (2011) determined the effects of concept mapping as a study skill on student's achievement in Biology. The major findings of this study indicated a significant and consistent improvement in Biology achievement as the period of experience with the use of the method increased. Also, students who used concept mapping as a study skill retained biological knowledge longer than those who used other methods. All the students interviewed in the concept mapping classroom agreed that concept maps helped them not only in the determination of the relationships among the concepts but also shaped their understanding of the concepts and increased their critical thinking. The findings of Hall, Dansereau, and Skaggs (1992), and Kinchin (2000a & 2000b) were similar to these research findings. Kinchin (2000a) found a significant impact of concept mapping on achievement when used for instructing secondary school biology students. Kinchin (2000b) in a study comparing the effect of the use of concept mapping as a study skill on students achievement, found a positive effect on students who used concept maps to revise and summarize the materials given.

Apart from studies which solely determined the effects of concept mapping on students' achievement, mapping has been used along with other instructional strategies and their combined effects on students' achievement determined. Whereas some studies showed significant improvement on students' achievement when concept mapping was combined with other instructional strategies, others found no significant differences. For example,

Okebukola (1989) investigated whether concept mapping alone as an instructional strategy in Biology would enhance meaningful learning when compared with concept mapping in cooperative learning groups. The study found a significantly higher achievement scores in Biology among students in the concept mapping group than those in class, taught with concept mapping and cooperative learning group.

Jegade, Alaiyemola and Okebukola (1992), comparing the effectiveness of concept maps as teaching strategy in Nigeria, and Ezeudu (1998), examining the effect of concept mapping on students' chemistry achievement in Enugu and Nsukka educational zones, found that students taught with concept mapping significantly performed better on achievement tests than those in the control group. These findings indicate that concept mapping facilitates meaningful learning and understanding of concepts in science. Mensah, Otuka and Ernest (1995), in a similar study in senior secondary schools in Ghana, found that concept mapping can be used as a pre-instructional and post-instructional tool in Biology.

Markwo and Lonning (1998) investigated the use of students' constructed maps and the effects the maps had on students' conceptual understanding of Chemistry experiment that they performed. They found that learning was enhanced and the construction of the pre and post instruction concept maps did help students understand the concepts in the experiments they performed.

Obianor (1997) and Ezeudu (1998) provided two opposing views on how concept mapping affect students' of different sexes. Ezeudu (1998), who studied the interaction effect between concept mapping and gender on achievement in Chemistry, found that the male students significantly out-performed the females in the achievement test administered. Obianor (1997) found that there was no significant difference in achievement between males and females taught with concept mapping. This is consistent with the finding of Ajaja, (2011) as earlier reported.

The major limitation of concept mapping is that it taps high cognitive ability and a very good mastery of the subject area. Low ability teachers and learners may not be able to draw and use concept maps for teaching and learning. Bennett (2003) identified two major limitations of the use of concept mapping in instruction. First, concept mapping is not easy to construct, and respondents require training and practice in producing maps. Second, there are difficulties with the interpretation of concept maps in particular with devising appropriate ways of scoring to enable valid comparisons to be made. Thus limitations are found to frustrate low achievers in mastering the techniques required for the use.

### *Cooperative Learning*

Cooperative learning is an instructional strategy which organizes students in small groups so that they can work together to maximize their own and each other's learning. Specifically, the cooperative learning approach to instruction is where students are arranged in pairs or small groups to help each other learn assigned material (Trowbridge & Bybee, 1996; Trowbridge et al, 2000). Interaction among students in cooperative learning groups is intense and prolonged (Borich, 2004). In cooperative learning groups, unlike self-directed inquiry, students gradually take responsibility for each other's learning. Borich (2004) and Trowbridge et al (2000) identified four basic elements in cooperative learning models. Small groups must be structured for positive interdependence; there should be face-to-face interactions, individual accountability, and the use of interpersonal and small group skills.

Cooperative learning has been found to be useful in several areas such as helping learners acquire the basic cooperative attitudes and values they need to think independently inside and outside the classroom (Borich, 2004, Johnson, Johnson & Holubec, 1990); promoting the communication of pre – social behavior; encouraging higher order thought processes; and fostering concept understanding and achievement (Borich, 2004; Johnson et al, 1990; Trowbridge & Bybee, 1996; Trowbridge et al, 2000). Cooperative learning brings together in adult-like settings which, when carefully planned and executed can provide appropriate models of social behavior (Steven & Slavin 1995). Steven and Slavin (1995) noted that if all other benefits of cooperative learning were not enough, the fact that it has been linked to increase in the academic achievement of learners at all ability levels is another reason for its use. Cooperative learning is known to actively engage students in the learning process and seeks to improve the critical thinking, reasoning, and problem solving skills of the learner (Bramlett, 1994; Megnin, 1995; Webb, Trooper & Fall, 1995).

A review of studies on the effects of cooperative learning on students' achievement indicated that cooperative learning gains are not limited to a particular ability level or sex but to all who engage in it (Ajaja & Eravwoke, 2010; Bramlett, 1994; Crosby & Owens, 1993; Glassman, 1989; Johnson, Johnson & Stanne, 1986; Megnin, 1995; Webb, Trooper & Fall, 1995). Stevens and Slavin (1995) linked cooperative learning to increase in academic achievement of learners at all ability levels. While studies by Glassman (1989) and Johnson, Johnson and Stanne (1986) found cooperative learning to emphasize the status and respect for all group members, regardless of gender. Very importantly, the study by Crosby and Owens (1993) found that different cooperative learning strategies can be employed to help low ability students who had difficulties making success in the traditional classroom to improve achievement.

A more recent study by Ajaja and Eravwoke (2010) reaffirmed the ability of cooperative learning when used as an instructional strategy to bring about significant improvement in students' achievement in school science subjects. The findings of the study indicated that students in cooperative learning group outscored those in the lecture group in an achievement test and a non – significant difference in achievement scores between male and female students in the cooperative learning group.

The major disadvantages of cooperative learning include:

- (i) not all members of a group will participate in solving the problems they are confronted with;
- (ii) some very active members of a group may overshadow less active ones;
- (iii) the method is time consuming; and
- (iv) low ability students who solely depend on the teacher for all information may not be able to make any contributions during cooperative learning.

### *Learning Cycle*

The learning cycle is a generic term used to describe any model of scientific inquiry that encourages students to develop their own understanding of a scientific concept, explore and deepen that understanding and then apply the concept to new situations (Walbert, 2003). The learning cycle is an established planning method in science education and is consistent with contemporary theories about how individuals learn (Lorsbach & Tobin 1997). It is useful in creating opportunities to learn science. There are different models of the learning



cycle, popular among these models are the three phase model, four phase model and the five phase model.

Moyer, Hackett and Everett (2007) stated that the learning cycle model of learning and teaching evolved for the past 40 years. The emergence of this model was influenced by the work of Jean Piaget and its application by Robert Karplus and Myron Atkin (1962), who applied cognitive development theory and discovery learning to instructional strategies in elementary science. Karplus and Myron Atkin with the support of the National Science Foundation developed a three phase learning cycle that served as the central teaching/learning strategy in the newly introduced science curriculum improvement study (SCIS) program (Atkin & Karplus, 1962).

The first three phase model of the learning cycle consisted of: Exploration, Invention and Discovery and were first used in the SCIS program (Moyer et al, 2007; Trowbridge et al, 2000). Continuing, they noted that these terms were modified to Exploration, Concept Introduction and Concept Application by Karplus. Moyer et al (2007) reported the observation of Barman and Kofar (1989) and Hackett and Moyer (1991) that the cycle evolved through modification to include additional phases such as engage, explore, explain, elaborate, extend and apply and are used to frame single guided discovery lesson as well as extend experiences such as chapters and units. They noted that a fifth phase, evaluate, was incorporated into an elementary science program developed by the Biological Science Curriculum Study (Biological Science Curriculum Study, 1992). These series of modifications gave birth to the model called 5E learning cycle the model used for this study.

The 5E cycle has even been further modified to show different forms and versions. However, the model specifically adopted for this study is the Bybee's 5E model which has five stages. The five stages include: Engagement, Exploration, Explanation, Elaboration and Evaluation. At all the stages, evaluation is done by the teacher to determine the level of learning.

Most empirical studies on the effectiveness of learning cycle when used as an instructional strategy found significant improvement in students' achievement, retention, attitude and correction of misconceptions. Studies by Baser (2008), Pulat (2009), Lee (2003), Lord (1999), Nuhoglu and Yalcin (2006), and Whilder and Shuttleworth (2004) found that students' achievement improved after the instruction of 5E learning cycle. Specifically, the empirical study by Lee (2003) found out that the students acquired knowledge about plants in daily life easier and understood the concepts better when taught with learning cycle. Pulat (2009) in another study determined the impact of 5E learning cycle on sixth grade students' Mathematics achievement and attitude towards the subject. The results showed that the students' mathematics achievement improved after the instruction of learning cycle.

Studies by Ajaja (1998) and Nuhoglu and Yalcin (2006) showed that learning cycle enhanced the retention of science knowledge. Nuhoglu and Yalcin (2006) specifically emphasized that learning cycle make knowledge long lasting and that students become more capable of applying their knowledge in other areas outside the original context. There appears to be scarcity of literature on the effect of learning cycle on retention when separated from achievement as a whole.

The major advantage of 5E learning cycle apart from other advantages associated with constructivist approaches to instruction is the creation of learning opportunities for students (Moyer et al, 2007). The approach offers students the opportunity to perform physical activities designed to answer questions raised by the teacher and students and at the same time engaged mentally. The approach may therefore be very appropriate for teaching for conceptual change.

Two major limitations can be identified with the 5E learning cycle. First, the method is time consuming. A method of instruction which involves as many as five stages may not be very suitable for achieving immediate lesson objectives. Secondly field dependent and low ability students who most often dependent on teachers for all information and directives may experience some difficulties using the approach for learning. However, these two limitations may be reduced through increasing instruction time for science subjects and re-emphasizing strong cooperation among students when the method is used.

### Theoretical Framework

This study is grounded on three theories, one on realist epistemology and education and two on pragmatist epistemology and education. The two theories under pragmatism are Piaget's theory of cognitive functioning development and Vygotsky's activity theory of learning. The basic principle of philosophic realism is that matter is the ultimate reality. The realists are of the view that the world we perceive is not a world that we have recreated mentally but the world as it is (Kneller, 1972). This epistemological stance suggests that the selection of the learning task for the student should be the responsibility of the school. The initiative in education, therefore, lies with the teacher, not the student, who must decide what subject matter can be made to satisfy the student personal needs and interest (Kneller, 1972). Kneller further stated that to instruct the student in the knowledge that matters most is the true end of education; satisfying the interest is only a means to this end, a useful teaching strategy. This specification and stand is clearly demonstrated in the lecture method of instruction.

The major principle in Piaget's Constructivist Theory of Cognitive Functioning is that learning is attained through 'construction' (Piaget, 1970). This theory suggests that human knowledge is innate and that human knowledge is directly shaped by experience. This theory sees learning as occurring based on the interaction between what the learner already knows and the physical environment. King (1998), while discussing Piaget's theory, noted that human beings are capable of extending biological programming to construct cognitive systems that interpret experiences with objects and other persons. This thought provides a model for building classroom instruction for small groups and individuals that will lead to practice and learning in the classroom. King (1998) argued that peer or small group interactions provide rich and necessary context for students to revise their current cognitive system which may lead to invention. The basic principle of this theory, which is creating knowledge through interaction between the learner and the environment perfectly, agrees with the fundamental structures of concept mapping, cooperative learning and 5E learning cycle. They all emphasize active participation in lesson through physical activities and mental engagement.

Vygotsky's Activity Theory of Learning sees learning as appropriation which resides within the learner. Vygotsky (1978) believed that a student's learning development is facilitated by social interaction with more sophisticated individuals who provide guidance during the learning process. The theory of zone of proximal development (Vygotsky, 1978) emphasize that children learn best if placed in an environment which requires thinking slightly above their developmental level. Vygotsky believed that learning development in such environment is facilitated by the social interaction among peers and between teachers and learners. Moyer et al (2007, p. 8) stated that from the work of Vygotsky, "it can be seen that the value of students working in small groups to conduct science investigations comes from the discourse that takes place". This reasonably follows that the skillful intervention of a teacher can elevate the level of students' thinking and learning. The structure of this theory also agrees with the principle of concept mapping, cooperative learning and 5E learning cycle in part, particularly in the area of skillful intervention of the science teacher to elevate students' thinking and learning, but more with the cooperative learning and 5E learning cycle because of the existence of social interaction among students in these two models to bring about learning.

### Statement of the Problem

A literature review suggests that although concept mapping, cooperative learning, 5E learning cycle, and lecture instructional strategies significantly improve science students' achievement and retention, the students taught with lecture method performed significantly less well than students taught with all the other three strategies. This development indicates a significant breakthrough in science education research in the identification and creation of alternative learning environments to lecture environment. However, a question may be asked as to whether these four instructional approaches will produce varying effects on students' achievement when used to teach specific school science subjects. This is a gap in the literature which needs to be filled to enable researchers and science teachers to fully appreciate the roles and effects of these four instructional strategies in the teaching and learning of science.

To guide this study, the following research questions were raised and answered.

1. Will there be any significant effect of concept mapping, cooperative learning, 5E learning cycle and lecture methods of instruction on students' achievement in Biology?
2. Will there be any significant difference in Biology achievement among students taught with concept mapping, cooperative learning, 5E learning cycle, and lecture methods?
3. Will there be any significant difference in Biology achievement between males and females taught with concept mapping, cooperative learning, 5E learning cycle and lecture methods?
4. Will there be any significant difference in the retention of biological knowledge among students taught with concept mapping, cooperative learning, 5E learning cycle and lecture methods?

### Research Design and Methodology

#### Design of the Study

The design employed for the study was a 4 (treatment) X 2 (sex) X 8 (test) pretest, post-test, delayed post-test, non-equivalent, quasi-experimental repeated measures. The

design consisted of four treatment groups (concept mapping, cooperative learning, 5E learning cycle and lecture groups), two sexes (male and female) and eight repeated testing (1 pre-test, 6 post-tests and 1 delayed post-test). On this design, only testing was the repeated measure. The repeated testing is shown diagrammatically as  $O_1 \times O_2 \times O_3 \times O_4 \times O_5 \times O_6 \times O_7 \times O_8$ .  $O_1$  stands for the pre-test while  $O_2 - O_7$  stand for two weekly post-tests given at the end of every two week's instruction with test items restricted to the two week's contents covered and drawn from the segment allocated to them in the test instrument called Biology Achievement Test (BAT).  $O_8$  stands for the delayed post-test. For the pre and delayed post-tests, the BAT was administered as a whole without time series testing.

The repeated measures design as shown in this study is appropriate and right considering the fact the same research participants in each of the experimental treatment conditions were involved. Johnson and Christensen (2000) stated that if all participants in a study are repeatedly measured under each treatment condition as in this study, the design is best described as repeated – measures design. They further noted that with the repeated – measures design; the investigator does not have to worry about the participants in the different groups being equated because the same participants participate in all experimental conditions. The participants, therefore, serve as their own control, which means that the participants in the various experimental conditions are matched (Johnson & Christensen, 2000).

The repeated measures design adopted for this study was framed under the interrupted time series design model for four groups – to be:

1. Pre-tested once;
2. Exposed to twelve week treatment;
3. Repeatedly post tested at two weeks intervals, and
4. Delayed posted once.

The single pre-test and repeated post-tests were favored for two major reasons. First, in Nigeria, evaluation of learning outcomes is based on continuous assessment and since the study lasted for twelve weeks, repeated post tests on content covered after two weeks was most appropriate. Second, it was used to establish baseline data through administering one single pre-test to establish confidence in the effectiveness of the methods considered and their treatment procedures. This reason agrees with Wiseman's (1999) stand that if a group scores approximately the same on each of the pre-test and then, after the treatment, improves significantly on the post-tests, the researcher has grounds for more confidence in the effectiveness of that treatment. Although the pre-test was administered once, each of the contents tested in the series of post-tests were copied from the instrument used for pre-test and the items were restricted to the contents covered in each of the two weeks instruction. It therefore boils down to the same effect which the series of pre-tests would have had.

The design was quasi-experimental because intact, comparative groups (classes) convenient and in place (acknowledging that assignments of individuals to groups have been made without the application of randomization procedures) were used. Wiseman (1999) stated that when the assignment of subjects to treatment groups follows these procedures as stated above, the design is described as a quasi-experimental design. In a similar vein, Campbell and Stanley (1963) stated that when a research person lacks the full control over the scheduling of experimental stimuli which makes a true experiment possible, collectively, such situations can be regarded as quasi-experimental designs. The introduction of sex as an

intervening variable into the design of the study shows a potential overlap of sex and teaching method on students' achievement.

### Sample and Sampling Technique

The sample of the study consisted of 259 senior secondary class (SSII) Biology students in eight intact classes from four senior secondary schools in Ika South Local Government Area of Delta State. There are forty (40) public secondary schools in the Local Government Area and from this population, the four selected schools were chosen based on the parameters of comparability and convenience. The parameters included presence of well-equipped laboratory, trained and experienced Biology teacher, mixed-gender school and school located within sixty (60) kilometers from researcher's place of work. Only the four schools used for the study met the specified conditions.

Eight Biology teachers were used for the study. Before they were selected, they were matched on the five criteria of sex, type of certificate possessed, professional qualification, years of experience and country of training. On the strength of this, only male Biology teachers who were graduates, professionally trained as Biology teachers, with between five to ten years of teaching experience and trained in Nigeria were selected. Two Biology teachers were selected from each school using the criteria stated above.

### Intervention

The intervention consisted of a twelve week instructional unit on Biology. During the unit the students 10 topics:

- (i) The cell;
- (ii) Diffusion and osmosis,
- (iii) Feeding definition and types and cellular respiration,
- (iv) Photosynthesis, chemosynthesis, and heterotrophy,
- (v) Excretion,
- (vi) Growth,
- (vii) Cell reaction to its environment,
- (viii) Types of movement,
- (ix) Reproduction and
- (x) Tissues and supporting systems.

### Instruments

One major instrument was used for the study. The Biology Achievement Test (BAT) consisted of 120 multiple choice test items constructed by the researcher and drawn from the 12 weeks instructional unit. The test items were arranged into six sets of twenty items each for administration at the end of every two weeks instruction. An example of test question is found in Appendix A.

#### *Content Validity*

The content validity of the BAT was achieved by a five-member panel consisting of three experienced Biology teachers drawn from three public senior secondary schools in Ethiope East Local Government Area of Delta State, one expert in Measurement and Evaluation, and one Biology educator. The five experts determined the content validity of the instrument by critically examining the contents of the test items, the content of the 12 week instructional unit and contents of table of specification. These three documents were made available to panel members to assist them in reaching a decision. The panel members worked

independently and forwarded their findings back to the researcher. The returns were collated and reviewed, and items were revised based on recommendations of the jury members.

#### *Construct Validity*

A pilot test was conducted to determine the construct validity, quality of individual questions, and estimate reliability of BAT. This involved the administration of BAT to 65 SSII Biology Students (independent group) in St. Charles College, Abavo (a secondary school) that agreed to participate in the pilot study. The characteristics of pilot group was similar to the characteristics of the population of SSII Biology students but were not part of the sample selected for the study.

Factors Analysis. The determination of Construct Validity of measurement of BAT involved a series of Factor Analysis being carried out. This involved the Extraction Method known as Principal Component Analysis and Rotation Method known as Quartrimax with Kaiser Normalization. On analysis of the responses of the 65 respondents the items were reduced from 132 to 120 by selecting only items with initial Eigen values of at least 1.

Item Difficulty. The difficulty of each item was determined with Kuder Richardson 20 procedure for estimating internal consistency of a test. This was accomplished by dividing the number of subjects who answered the item correctly by the number of subjects who made attempts. The range of possibilities is between 0.00 and 1.00 (Wiseman, 1999). The higher the difficulty index, the easier the question. Wiseman specifically stated that items with difficulty indices of 0.00 – 0.2 are too difficult while those with 0.8 – 1 are too easy. Based on this recommendations only item with difficulty indices of 0.3 – 0.7 were selected into the test instrument.

#### *Estimate of Reliability*

The reliability of BAT was calculated with Kuder Richardson 21 approach which specifically gives an estimate of the internal consistency of the instrument. This involved the analysis of the responses to items in the instrument to determine the number of items on the test, the arithmetic average (mean), and the variance of the scores (standard deviation squared). All these information were substituted to Kuder Richardson 21. The reliability index obtained was  $r = 0.86$ . This result showed that the instrument was reliable and suitable for the study. This agreed with the recommendations of Leedy and Ormrod (2005), Johnson and Christensen (2000), Thorndike and Hagen (1997), and Wiseman (1999) that reliability has to do with accuracy and precision of a measurement procedure, a high reliability value of 0.70 or higher shows that the test is reliable (accurately) measuring the characteristic it was designed to measure. On the strength of the results of content validity, factor analysis, item difficulty and reliability of the instrument, the instrument was used for data collection.

#### Treatment Procedure

The treatment procedure adopted was a combination of four treatment steps used in similar studies by Ajaja and Eravwoke(2010), Ajaja (2011), Ajaja and Eravwoke (2012) and Ajaja (2005).The eight instructors (two per group) used for the study were trained separately on the skills of using concept maps(Appendix B), cooperative learning (Appendix C), 5E learning cycle (Appendix D) and lecture (Appendix E) methods of teaching for four days lasting for two hours per day. Three other specialists on instruction joined the researcher in training the instructors on the teaching. The first day was spent discussing the theories, origin

and characteristics of the four instructional strategies. On the second day, the instructors were trained using the training manuals developed by the researcher; one manual each for concept mapping, cooperative learning, 5E learning cycle and lecture methods. The training manuals specifically defined the steps and stages involved in using each method and the specific roles teachers and students should play in each stage. The third and fourth days were spent on practice and generation of ideas on how to apply each method in the teaching of the selected concepts. The training came to a close when the researcher and the three other resource persons were convinced that the biology teachers trained can accurately apply the strategies in teaching the selected concepts.

A week before the commencement of treatment, all eight Biology teachers were given extracts which contained the contents in the twelve week instructional unit. The extracts were taken from *Modern Biology for Senior Secondary Schools* by Ramalingan (2008) and *Biology: Principle and Exploration* by Johnson and Raven (1998). Lesson plans written on each of the concepts in the 12 week instructional unit using the four methods teaching formats were given to the specific teachers assigned to use for teaching. This was done to ensure that all the instructional presentations followed the recommended formats for the designated classes. The lesson plans specified both the teachers' and students' activities during instruction.

Two days before the instruction began, groups were pre-tested with the 120 items on the BAT. This was done to determine the equivalence of the groups before treatment and to be sure that any noticed change later was due to the treatment. On treatment, and in each of the specific classrooms where instructional strategies were applied, the teachers used the methods on with they were trained.

At the end of every two weeks' instruction a post achievement test of 20 items selected from the BAT instrument and restricted only to contents taught in every two weeks was administered to all the four groups. This was done for the purpose of effecting continuous assessment directive demanded by the Nigerian educational system and determining the effectiveness of treatment as the period of experience with method increased. The students' test scores were averaged at the end of the 12 weeks of instruction to present a single post – test score. Four weeks after the post-test, a delayed post-test using the full BAT instrument as used in pre-test was administered to the four groups with the intention of estimating the retention of the knowledge taught long after the end of treatment. The data collected are summarized in tables under result.

## Result

Three statistics were used for the analysis of the collected data. Analysis of Covariance (ANCOVA) was used to test for significant differences among achievement test score means for all the groups. Analysis of variance (ANOVA) was used to compare the males and females in the four treatment groups on achievement and to compare the retention among the four groups. For paired samples, t – test was used to test for significant difference between students' pre-instructional and post- instructional test scores.

**Table 1 comparison of pre and post-test achievement means of concept mapping, cooperative learning, 5E learning cycle and lecture groups and t – test comparison of pre and post-test means**

Groups	N	Pre-test $\bar{X}$	Post-test $\bar{X}$	df	t	Critical t
Concept mapping	64	25.28	43.42	63	18.07	2.00
Cooperative learning	67	25.40	49.41	66	19.630	1.994
5E Learning cycle	69	25.45	50.21	68	21.90	1.994
Lecture	59	25.39	36.97	58	9.143	2.00

With respect to the pre-test scores, all the participants in four groups were equivalent regarding the knowledge of the concepts taught before the treatment as shown in Table 1. This was demonstrated by comparison of their mean scores and confirmed with the ANOVA test. The ANOVA comparison of groups shown in Table2 indicated non-significant difference  $F = 2.1752$ ,  $P > 0.05$ .

**Table 2 ANOVA comparison of pre – test scores of concept mapping, cooperative learning, 5E learning cycle and lecture groups.**

Source of variation	SS	df	MS	F	P – value	F crit
Between groups	552.6957	3	184.2319	2.175247	0.091233	2.63779
Within groups	23036.96	272	84.69469			
Total	23589.65	275				

On the post-test scores, Table 1 showed that students taught with 5E learning cycle scored the highest marks. This was followed by students in the cooperative learning, concept mapping and lecture groups respectively. All the students in concept mapping, cooperative learning and 5E learning cycle groups scored higher marks than those in the lecture group. On the t-test comparison of the pre-test and post-test means, the data indicated significant effects of all the instructional methods on achievement.

**Table 3 ANCOVA summary table comparing concept mapping, cooperative learning, 5E learning cycle and lecture groups on achievement with pre-test as co-variant**

Source of variation	Type III sum of square	df	Mean s square	F	Sig
Corrected model	16193.423a	7	2313.346	27.297	.000
Intercept	11369.407	1	11369.407	134.157	.000
Pre	8263.709	1	8263.709	97.511	.000
Method	7296.140	3	2432.047	20.557	.000
Sex	46.823	1	46.823	0.894	0.345
Method * sex	78.817	3	26.272	0.501	0.682
Error	21271.462	251	84.747		



Total 568086.790 259

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Table 3 which compared achievement test scores of students in the concept mapping, cooperative learning, 5E learning cycle and lecture groups indicated a significant difference among the groups. The calculated F was found to be greater than the critical F, which implied that  $F = 20.557$ ,  $P < 0.05$ .

With respect to interaction between sex and method of instruction on achievement, a non-significant interaction effect was found, shown in Table 3. This was based on the fact that the calculated F value is less than the critical F value,  $F = 0.501$ ,  $P > 0.05$ . This meant that the sex of the students did not really combine with the methods of instruction to influence their post test scores in the various instructional groups.

**Table 4 Scheffe post – hoc test to compare the concept mapping, cooperative learning, 5E learning cycle and lecture groups**

Dependent Variable	(I)Method of instruction	(J) method of instruction	Mean difference (I-J)	Std.error	Sig
Post-test	Lecture group	5E learning cycle group	-13.42444*	1.92869	.000
		concept mapping	-6.63739*	1.96311	0.11
		cooperative group	-12.62163*	1.9419	.000
	5E learning cycle group	Lecture group	13.42444*	1.9286	.000
		Concept mapping	6.78705*	1.88764	.005
		Cooperative group	.80281	1.86559.980	.980
	Concept Mapping	Lecture group	6.63739*	1.9631	.011
		5E learning cycle group	-6.78705*	1.8876	.005
		Cooperative group	-5.98424*	1.90115	.021
Cooperative Group	Lecture group	12.62163*	1.94192	.000	
	5E learning cycle group	.80281	1.86559	.980	
	Concept mapping	5.98424*	1.90115	.021	

The Scheffe test is a test used to show the direction of significance when significant difference is established. The Scheffe post-hoc test shown in table 4 indicated the following: (a) all the students in the concept mapping, cooperative learning and 5E learning cycle significantly obtained higher scores than those in the lecture group; (b) students in the cooperative learning and 5E learning cycle groups significantly obtained higher scores than

those in the concept mapping group; and (c) students in the cooperative learning and 5E learning cycle groups obtained scores that did not significantly differ.

**Table 5 Comparison of post-test scores of males and females in concept mapping, cooperative learning, 5E learning cycle and lecture groups by mean and ANOVA.**

Groups	N	Male $\bar{X}$	Male N	female $\bar{X}$	Female N	df	F	Fcrit
Concept mapping	64	42.57	34	43.61	30	63	0.2020	3.9958
Cooperative learning	67	50.71	32	48.84	34	66	0.6205	3.9909
5E Learning cycle	69	48.73	37	50.74	32	68	0.5192	3.9840
Lecture method	59	37.144	29	36.43	30	58	0.0619	4.0098

On comparison of post-test scores of males and females, all the male and female participants in the concept mapping, cooperative learning, 5E learning cycle and lecture groups did not significantly differ on the knowledge of concepts taught (Table 5). This was determined by comparison of their mean post-test scores and confirmed with ANOVA test. In all the groups, the calculated F values were less than the critical F values (Table 5).

**Table 6 comparison of  $\bar{X}$  scores of groups taught with concept mapping, cooperative learning, 5E learning cycle and lecture on retention.**

Groups	N	Average	SD
5E learning cycle	69	90.7	4.77
Cooperative learning	64	88.43731	6.14
Concept mapping	67	81.1125	6.55
Lecture method	59	76.1661	6.2009

Table 6 which compared the mean estimated retention of students taught with the four methods, indicated that students taught with the 5E learning cycle method retained more of the biological knowledge (90.7%) than those taught with concept mapping, cooperative learning and lecture methods respectively. On ranking of retention, among the groups, the group taught with 5E learning cycle method was followed by the group taught with cooperative method (88.44%), the next was the group taught with concept mapping with (81.11%) while the group taught with the lecture method had the least (76.16%). The noticed difference on retention scores among the students taught with concept mapping, cooperative learning, 5E learning cycle and lecture methods was confirmed with ANOVA test.

**Table 7 ANOVA summary table comparing students in concept mapping, cooperative learning, 5E learning cycle and lecture method on retention.**

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	8522.108339	3	2840.703	80.64771	.05	2.640001
Within groups	8982.01892	255	35.22236			

Total 17504.12726 258

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The ANOVA comparison of the groups (Table 7) indicated a significant difference,  $F = 80.6477$ ,  $P < 0.05$ . This was based on the fact that the calculated F-value of 80.64771 is greater than the critical F-value of 2.640001 at 0.05 level of significance.

### Discussion

A focus of research in science education is to isolate the appropriate methods and strategies which may lead to effective teaching and cause effective learning by students. A review of literature on instructional methods indicated that new methods and strategies are periodically recommended for science teaching and learning. For each of these new methods convincing proofs of their effectiveness in science teaching and learning are demonstrated. However, it is obvious that not all these strategies and methods are appropriate for all subjects and conditions. In most cases, the science teachers are at cross roads as to which methods are most appropriate for teaching the different science subjects. This study therefore, is not only timely but significant in the sense it will reduce the frustration science teachers, in general, and Biology teachers in particular, face in their choice of the most appropriate method among these four popular methods for effective teaching and learning.

The most significant findings are the large effects of the instructional methods on students' achievement and retention. The non-significant difference between males and females on achievement and retention in all the instructional methods was expected. The higher achievement of students in the constructive teaching groups (5E learning cycle, cooperative learning and concept mapping) is noteworthy, as is the lower achievement and retention of students in the lecture group. The ANCOVA and ANOVA analyses showed that the method of teaching does predict students' achievement in groups with varying instructional methods.

However, while the unique and significant effects of 5E learning cycle, cooperative learning and concept mapping on students' achievement over and above lecture method is applauded, there are several specific observations that were made about the findings in relation to the various instructional methods. First, the analysis indicated that all methods had significant effects on students' achievement in Biology. Since the post-test scores of all the students in all the groups were significantly greater than their pre-test scores, it therefore follows that the post achievement test scores was earned not by chance but as a result of treatment with the prescribed instructional methods. This implies that all the methods compared have the potential to cause learning to take place but at varying degrees which is the bases for this study. The ability of this study to establish a cause and effect relationship as found, agrees with the principle of experimental research as recommended by Borich (2004), Johnson and Christenson (2000), and Wiseman (1999). They all agreed that in experimental research, a treatment must be confirmed to be responsible for any difference noticed.

Secondly, the analyses showed a significant difference in achievement scores among the four instructional groups. The variations in achievement scores among the groups may be due to the variation in the teaching strategies adopted in each of the groups and their comprehension of the methods of instruction. This may have translated into influencing their

scores in the achievement test. The post hoc analysis which indicated that all the students taught with concept mapping, cooperative learning and 5E learning cycle strategies outscored those taught with lecture method suggests that the students in these groups may have been more active in the learning process than those in the lecture group and thus contributing to their higher achievement scores. This is hinged on the fact that students learn better by doing. The low achievement scores as found among the students taught with lecture method may not be unconnected with the transmission approach involved, where the teachers pass over their knowledge to their pupils.

The significantly higher achievement of students taught with concept mapping, cooperative learning and 5E learning cycle over those taught with lecture method as found in this study is consistent with the findings earlier researchers made on this same subject matter. Nevertheless, higher achievement of students taught with cooperative learning and 5E learning cycle over those taught with concept mapping, the limitations ascribed to concept mapping may be the possible explanation for the lower score. These limitations may have frustrated the low achievers particularly and resulted in their lower achievement scores to produce the lower mean found with the group. The non-significant difference in the achievement scores between students in the cooperative and 5E learning cycle groups may be explained with the very active participation of students in learning process and the cooperative activities which go on during instruction with the two methods. This may have influenced the students' effective learning and understanding of the concepts they were exposed to equally.

Thirdly, the analyses also found a non-significant interaction effect between sex and method of instruction on achievement. This simply means that the combination of the sex of students and the methods used for instruction does not influence achievement in Biology. This therefore implies that the noticed significant differences in achievement scores among students taught with concept mapping, cooperative learning, 5E learning cycle and lecture methods may not be linked to sex but entirely to the methods of instruction. It therefore follows that the degree of achievement earned by students in the various instructional groups may be hinged on the effectiveness of the methods. This finding agrees with the intention and recommendation of science education researchers that whatever method that should be adopted for science teaching should be such that enables students to learn equally, irrespective of sex. This disposition is most relevant now that there is a deliberate effort to bridge the gap between males and females on representation in science.

Fourthly, the analyses once again showed that no significant difference exists between the males and females in the concept mapping, cooperative learning, 5E learning cycle, and lecture groups. This finding, therefore, suggests that the four instructional methods are suitable for science teaching and learning. This position is based on the fact that the major objective of science education research is to identify and isolate instructional methods and strategies which will enable all students irrespective of sex and ability to learn equally. This finding is consistent with the findings of researchers in the past on the same issue.

Fifthly, the estimated retention determined with the delayed post – test, the analysis showed that students taught with the 5E learning cycle, cooperative learning, concept mapping and lecture method, retained a reasonable percentage of the concepts taught after four weeks of initial treatment. However, the margin of retention varied among the four methods used for instruction. Shown in Table 6, the order of retention followed this

sequence: 5E learning cycle group 90.7%, Cooperative learning group 88.44%, Concept Mapping group 81.11% while lecture group 76.16%. The ANOVA comparison of the four groups indicated significant difference among the groups while post hoc analysis on retention indicated that students taught with 5E learning cycle and cooperative learning significantly retained more than those taught with concept mapping and lecture methods. No significant difference was, however, found on retention between students taught with 5E learning cycle and cooperative learning methods. Students taught with concept mapping were found to retain more than the lecture group. Lecture method was the last on ranking of retention among the four methods. The finding of significant retention by students in all the instructional groups agreed with what initial researchers found using the various methods.

The noticed lower retention of biological knowledge by students taught with lecture method and concept mapping than those taught with 5E learning cycle and cooperative learning, may not be unconnected with the earlier identified limitations associated with the two methods. The problem of the difficulties in the construction of concept maps and their interpretation as pointed out by Bennett (2003) may have frustrated particularly the low ability students in the effective learning and retention of the concepts they were exposed to. While in the lecture group, the transmission approach adopted by teachers and the passive role played by students may have made the knowledge they acquired to be easily forgotten after a short period of time. These may have resulted in the lower retention found. The non-significant difference on retention between students in the cooperative learning and 5E learning cycle groups as found in this study may be explained with the very high level of engagement of students in the learning process. To apply cooperative learning in the Biology teaching involved 18 steps while the application of 5E learning cycle in the classroom entails five stages all of which are shown in the treatment procedure. These series of activities may have influenced the internalization of the concepts taught and their eventual retention for a longer time.

### Conclusion

The findings of this study indicated that all four instructional methods showed significant effects on students' achievement as measured with immediate post-test and delayed post test to determine retention. There were however, variations in the levels of achievement among students in the four instructional groups compared. The variation in the levels of achievement among students taught with the different strategies was a direct reflection of the philosophical theories under which the methods evolved. The instructional method framed under the realist ideals produced students with lower scores, while the methods hinged under pragmatic ideals produced students who scored higher marks because of the varying level of students' activities in the lessons. Among the methods with pragmatic ideals, methods with features of social interaction among the students, produced students with the highest scores because of bonds of relationship established. Students in the 5E learning cycle and cooperative learning groups for example were found to score higher marks both in immediate achievement and retention tests probably because of the interplay of a higher students' activity during the lessons and social interaction which is a significant feature in the structure of the two methods. Students in the concept mapping and lecture groups followed respectively probably because of the reduced degrees of students' activities and social interaction. The difference in test scores of students in learning cycle and cooperative learning groups was however not significant. The conclusion therefore is, since the major objective of science instruction is for students to learn effectively, it is very obvious from the

findings of this study that the better methods for teaching and learning Biology could be either the learning cycle or cooperative learning. These methods will however be very effective only if the laboratory facilities for science teaching and learning are available in schools, considering the numerous steps involved in their use. In schools where laboratory facilities for Biology teaching and learning are not available, a better alternative to the lecture method remains the concept mapping since the method does not essentially demand the use of laboratories for practice. However, before the adoption of the method as an appropriate instructional strategy, both the teachers and students should be well trained to acquire the skills necessary for its use. The efficient acquisition of the skills necessary for its use both by the Biology teachers and students will reduce the limitations associated with the method. Lecture method could still be used to teach very abstract topics to enable students easily acquire knowledge, new information, and explanation of events or things. It will reduce the frustration students will experience with the other methods when dealing with very novel concepts.

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**Appendix A****Sample of Test Items in BAT****Instruction: Answer all questions, each correct answer attracts 1 mark****Each questions is followed by four options****Time Allowed: 20 minutes**

1. The term cell can best be described by which of the following? Answer: C
  - A. the smallest unit
  - B. the smallest organism
  - C. the smallest unit of life
  - D. the smallest indivisible organism
  
2. Eukaryotic cells differ from prokaryotic cells in that eukaryotic cells .....Answer: D
  - A. lack organelles
  - B. have DNA, but not ribosomes
  - C. are single-celled
  - D. have a nuclear membrane
  
3. Cell exists in the following forms except.... Answer: B
  - A. independent form
  - B. mass
  - C. colony
  - D. filament
  
4. The term “cell” was first used by .... Answer: B
  - A. Robert Hooke in 1628
  - B. Robert Hooke in 1665
  - C. Robert Hooke in 1668
  - D. Robert Hooke in 1672
  
5. Organelles that are present in plant cells but absent from animals cells include the ....Answer: A
  - A. Chloroplast and central vacuole
  - B. flagellum and cell wall
  - C. mitochondria
  - D. endoplasmic reticulum, cell wall and lysosomes
  
6. The organelle which packages and distributes proteins and lipids is.....Answer: B
  - A. endoplasmic reticulum
  - B. golgi apparatus
  - C. lysosome
  - D. nuclear envelope
  
7. The organelle which acts as the central power house is.....Answer: C
  - A. lysosome
  - B. ribosome
  - C. mitochondrium

D. golgi apparatus

8. Which of the following does the chloroplast do in a cell? .....Answer: D

- A. Capture water
- B. capture carbon dioxide
- C. capture oxygen
- D. capture sunlight

9. In which of the following organelles is protein manufactured in the cell? .....Answer: C

- A. rough endoplasmic reticulum
- B. smooth endoplasmic reticulum
- C. ribosome
- D. vesicle

10. The activities of the cell is directed by .....Answer: C

- A. Chromosomes
- B. mitochondria
- C. nucleus
- D. lysosomes

11. The spontaneous movement of any molecule from an area of high concentration to an area of low concentration is.... Answer: B

- A. Osmosis
- B. diffusion
- C. equilibrium
- D. active transport

12. Which type of molecules most easily move across a membrane? Answer: A

- A. Hydrophobic molecules, like  $N_2$
- B. large polar molecules, like glucose
- C. ions, like chloride ( $Cl^-$ )
- D. small, uncharged polar molecules, like water

13. Distilled water is ..... relative to a solution containing dissolved salts.

Answer: B

- A. hypertonic
- B. hypotonic
- C. isotonic
- D. none of the above

14. A red blood cell placed in distilled water will..... Answer: C

- A. remain unchanged
- B. lose water and shrink
- C. gain water and expand
- D. none of the above

## **Appendix B**

### **Concept Mapping Strategy**

**Concept Mapping Classroom.** Subjects in this group were introduced to and trained on how to construct concept maps following the procedures of Novak and Gowin (1984). For example, to create a concept map, start with what you already know. Build from what is familiar. What are the key components or ideas in the topic you are trying to understand? Place each concept in its own individual cycle, box or other geometrical shapes. Label each arrow with descriptive terms so that your diagram can be read as a statement or proposition by following interconnections from the top to down. With these steps learned and understood, the students practiced the construction of several concept maps before the commencement of instruction. A specific application of concept mapping to teach a topic is shown below.

#### **Application of concept mapping to teach “Forms in which cells exist”**

##### **Procedure**

**Step 1** The focus question or key topic of what was to be taught was defined as “Forms in which cells exist”.

**Step 2** With the key topic identified, the most important and general concepts associated with the topic were listed together with the students. The key concepts listed included; Independent Forms, Multicellular Forms, Organisms, Colony, Filament, Ball, Long Strand, Single celled plants, Single celled animals, Living things, and all organisms are made of cells.

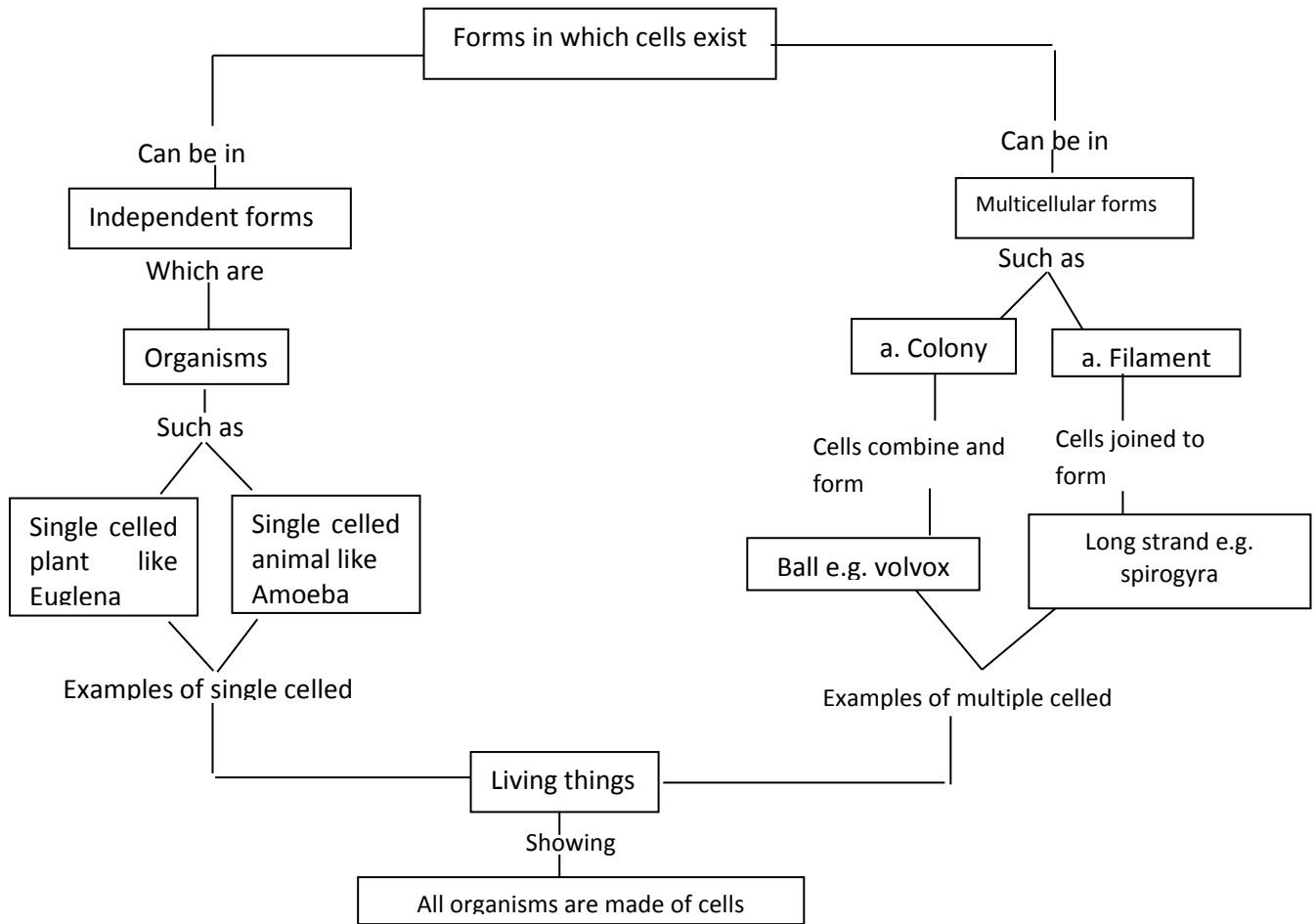
**Step 3** The identified concepts were listed from the most general and inclusive to the most specific see Fig 1 for details.

**Step 4** Links were added as shown in Fig. 1 to form a preliminary concept map. The students participated in drawing the links.

**Step 5** The teachers together with the students added phrases to describe the relationship among concepts. Some of the phrases used included: *can be in, which are, such as, examples of, showing and others.*

**Step 6** After building the preliminary concept map, the instructors together with the students, determined and drew cross links that linked all concepts from different areas or sub-domains on the map to elaborate on how the concepts are interrelated.

**Step 7** The teachers and the students reviewed the concept map and made some necessary changes both in content and correction.



**Fig. 1. Concept map of forms in which cells exist**

On treatment, the students taught with concept mapping strategy were first asked to read the extracts they were presented and construct a pre – instruction concept map at home. This was followed with 60 minutes, instruction on concepts in the various weeks’ instructional units, using concept mapping. Students provided main concepts, cross links, linking phrases or complete map. After this, the students did the study, and turned in assignments at the end of every week’s instruction. The students were found to have restructured their concept maps briefly during the class instruction and extensively as homework after each week’s instruction. This post instruction concept map constituted the group’s understanding of the concepts learned in the units of instruction.

## **Appendix C**

### **Cooperative Learning Strategy**

**Cooperative Learning Classroom.** The number of students in each cooperative groups were four. The teachers who taught the cooperative – learning group incorporated the basic elements of cooperative learning into the group’s experience: positive interdependence, face-to-face interaction, individual accountability, social skill development, and group processing as recommended by Johnson, Johnson and Holubec (1990). In addition, the teachers specified both the academic and social skill objectives, explained the tasks and goal structures, assigned roles within the groups and described the procedure for the learning activities as demonstrated by Trowbridge and Bybee (1996) and Trowbridge et al, (2000). During the treatment period, students in the cooperative learning classrooms were instructed by the teachers who followed the guidelines learned during their training. The highlight of the contents in the training manual included the following: (1) stating the objectives for the lesson; (2) deciding on group size; (3) deciding on who is to be in the group; (4) deciding on the room arrangement; (5) deciding on the instructional materials to promote interdependence; (6) deciding on roles to ensure interdependence; (7) explain the assignment; (8) explain collaborative goal; (9) explain individual accountability; (10) explain intergroup cooperative; (11) explain the criteria for success; (12) explain the specific cooperative behaviours; (13) monitor student work; (14) provide task assistance; (15) teaching collaborative skills; (16) provide closure for the lesson; (17) evaluate the quality and quantity of student learning; and (18) assess how well the groups functioned. A specific application of cooperative learning to teach a topic is shown below:

#### **Application of cooperative learning to teach “Forms in which cells exist”**

##### **Procedure**

**Step 1. Gaining attention.** The teachers asked the students to form groups of four students each which must be heterogeneous both in sex and ability. To make sure that this was achieved, they personally assigned some students to some groups to act as a model.

**Step 2.** They asked the students to seat in a circle facing one another and close enough for effective communication.

**Step 3. Informing the learners of the objectives.** In this lesson we will learn about the forms in which cells exists. We will specifically define cell and classify cells into two: Independent form and multicellular form. We will further classify multicellular organisms into: (i) those that have colony of cells and (ii) those made of cells which form filament.

**Step 4. Deciding on the instructional materials to promote interdependence.** The 9 created groups each of the cooperative classes for example, were given numbers from 1 to 9. Based on the three forms in which cell exists, instructional materials were distributed among the various groups.

The instructional materials were mainly photocopies of assigned readings on cell, specimens containing organisms of different cell forms, slides and microscopes. Each group had resources needed by the group for their specified assignment. Other groups’ resource materials were also made available to varying groups for the purpose of inter-group cooperation and relationship.

**Step 5. Deciding on roles to ensure interdependence.** The teachers took each of the groups and assigned special roles to members. For example John, you are the recorder, Judith, you are the researcher, Pat, you are the summarizer, and Uche, you are the observer. This essentially encouraged cooperation among group members.

**Step 6. Introduction of lesson topic by stimulating recall of prerequisite learning.** The teachers told the students: “you have heard of how plants and animals, originated”. “You have even heard of the term cell”. This means that living things whether plants or animals are made of cells.

**Step 7. Explain the assignment.** The teacher explained the assignments to the students using the various groups as specific entities. In this lesson, each group is to study the assigned reading materials which are on cell with emphasis on cell forms. Depending on the type of study materials which your group has, be ready to answer the following questions at the end of the lesson: (i) what is cell? (ii) list the forms in which cells exist and with specific examples? (iii) what features do cells have in common? (iv) what features bind cells in a colony together? (v) what theory can we prove with this inquiry?

**Step 8. Explain the collaborative goal.** My dear students, noted by the teachers, you must understand that you are responsible for doing this assignment and learning the materials, and that all group members learn the material and successfully complete the assignment.

**Step 9. Explain individual accountability on the topic: “Forms in which cells exist”** The teachers advised thus, you must understand that you are responsible for your learning and you will assess learning on your individual level.

**Step 10. Explain the criteria for success.** The teachers instructed thus, students; I wish to advice that you take this assignment very seriously because your scores will be based on your ability to answer the questions drawn from the set objectives on forms in which cells exist.

**Step 11. Explain the specific cooperative behaviours.** The teachers informed the students thus, for you to understand very well and clearly too, all the concepts in your assigned study materials on forms in which cells exist, you must stay as a group, talk quietly, each person should explain how he/she got the answer, listen to other group members and criticize ideas not people.

**Step 12. Monitoring and intervening.** The teachers moved round the seats of the various groups in their classrooms to inspect what they are doing. Group 1 working on cell as independent organism, have you been able to find solutions to my questions? Answer these questions - - - one after the other. Group 2, you studied cells as a colony, teach us too what you learnt about filamentous cells and examples of organisms existing as filaments.

**Step 13. Summary.** The teachers in their respective classes notes thus, I have listened to all your presentations and have seen areas where there are few problems. I will now summarize all your presentations and make appropriate corrections to enable you all make corrections on your own. The teachers then makes the summary right from definition of cell, through forms of cells (independent cell, colony and filament), examples of organisms with

the various cell forms, similarities among cells, features which connect cells in a colony together to form an organism, and finally ended with cell theory.

**Step 14.Evaluation.**Students, noted by the teachers, at the end of this lesson all the groups will submit their reports for assessment. In the next lesson we will use part of the time to openly talk about how the groups functioned. You will all have the opportunity to ask questions and make your suggestions.



## Appendix D

### 5E Learning Cycle Strategy

**5E Learning Cycle Classroom.** In the 5E learning cycle classroom, the teachers who taught there performed the following activities by applying the procedures recommended by Trowbridge and Bybee (1996), Bybee (1997), Trowbridge et al (2000), Walber, (2003) and Lorsbachand Tobin (1997) strictly. The stages include:

- **Engagement**

The teachers posed problems to get the students attention. This was followed by pre-assessing student's prior knowledge on the topics. They went ahead to inform students of the lessons objectives. The students were reminded of what they already know that they need to apply in learning the topics at hand. The teachers finally posed problems for students to explore in the next phase of the learning cycle. This formed the point from where the next lesson begins.

To evaluate engagement, the teachers asked specific questions on the topics at hand to determine students' prior knowledge. These the students answered orally.

- **Exploration**

The purpose of exploration is to have students collect data that they can use to solve the problems that were posed. The teachers specifically asked the students to do the following: (i) Think freely but within the objectives of the lesson; (ii) test predictions and hypotheses; (iii) form new predictions and hypotheses; (iv) try alternatives and discuss them with others; (v) record your observations and ideas; and (vi) suspend judgment.

To evaluate exploration, the teacher asked themselves the following questions in their minds: (i) How well, are the data being collected by students? (ii) Are the procedures being carried out correctly? (iii) How are the collected data being recorded? (iv) Is it orderly?

- **Explanation**

The teachers engaged the students in discussion and asked them to do the following at the explanation stage:

- (i) Explain your answers to others;
- (ii) Listen critically to one another's explanations;
- (iii) Question one another's explanation;
- (iv) Listen to and try to comprehend explanations offered by the teacher;
- (v) Refer to previous activities to guide your explanations; and
- (vi) Use recorded observations in explanation. The teachers at this stage introduced new vocabulary, phrases, or sentences to label what the students have already found out and guide them to arrive at correct conclusions.

To evaluate explanation, the teachers asked the students questions on the process of data collection and use of the data in explanation and arriving at conclusions. The teachers also asked students questions on the introduced terms to determine their comprehension.

- **Elaboration**

The teachers gave students new information that extended what they have been learning in the earlier parts of the learning cycle. The questions raised at this level enabled the students to do the following:

- (i) Apply new definitions, explanations and skills in new but similar situations;

- (ii) Use previous information to ask questions, propose solutions, make decisions and design experiments;
- (iii) Draw reasonable conclusions from evidence;
- (iv) Record observation and explanations; and
- (v) Check the understanding among peers.

In the evaluation of elaboration, the teachers asked exactly the kind of questions that come under evaluation. The question types are shown under evaluation below.

- **Evaluation**

These kinds of question were asked students by the teachers at the end of the lesson.

- (i) Open-ended questions by using observations, evidence, and previously accepted explanation;
- (ii) Demonstrate an understanding of knowledge of the concept of skills;
- (iii) Evaluate students own progress and knowledge; and
- (iv) Related questions that would encourage future investigation.

A specific application of 5E learning cycle to teach a topic is shown below.

### **Application of 5E learning cycle to teach “Forms in which cells exist”**

#### **Procedure**

**Step 1 Engage.** “Look at the diagrams of the cells that are on the whiteboard” the teachers instructed. “Have you seen the diagram of the cell before? How does it remind you of what plants and animals are made of? What are the parts of a cell? In what forms do cells exist? You will observe some small organisms under the microscope to identify their cell make-ups. Find out how cells combine to form an organism. In this lesson we will investigate this single question: in what forms do cells exist?”

**Step 2 Explore.** The teachers instructed thus: “(1) Watch the organisms in containers labeled A, B, C and D under the microscope to identify their cell make-ups.

(2) Make labeled diagrams of the cell make-ups of the identified organisms.

(3) For each of the identified organisms, how many cells were your about to count?”

**Step 3 Explain.** The teachers directed thus: “Use your observations and drawings to answer the following questions

- (i) In how many forms do cell exist?
- (ii) List the forms in which cells exist?
- (iii) Does a particular cell form exist only in a plant or an animal?
- (iv) Give examples of other organisms different from the ones you have observed that show the various forms in which cells exist.”

**Step 4 Extend.** The teacher directed as follows: “Select any of the multicellular organisms you have identified earlier and do a detailed investigation of it. (a) How many cells does it have? (b) What features do the cells have in common? (c) How were the various cells connected to form the organism? Plan how to identify these features to enable you solve the problems and give the outline.

(d) Record your findings

(e) Share your findings with other student groups.”

**Step 5 Evaluation.** The teachers asked the following questions: “(a) Based on what you know about the forms in which cells exist what are living things made of? (b) what name can we give to the theory that this lesson has investigated.”

**Note;** At all stages, the teachers acted as the facilitators while the students carried out the assignments themselves and arrived at conclusions most times by themselves.

## **Appendix E**

### **Lecture Strategy**

**Lecture Method Classroom.** The group taught with lecture method was taught the same content just like in concept mapping, cooperative learning and 5E learning cycle groups. The teaching in this group was textbook centered but instead of discussing the materials, helping each other, or developing projects in groups, students read the assigned reading materials silently, completed assignments independently and at their seats, engaged in discussion with the teachers in response to teachers questions (Ajaja & Eravwoke, 2010). The teachers who taught the lecture group mainly presented contents and facts to the students in their final forms. Exactly the same procedure was continued throughout the twelve weeks of instruction.

Specifically, the teachers who used the lecture method to teach their groups “forms in which cells exist”, first of all informed the students of the topic to be taught. The teachers went ahead to inform the students of the objectives to be achieved. Highlights of the instructional materials available for teaching the topic were shown. The teacher after discussing the previous knowledge with the students for a very short period, explained to the students what the cell is, forms in which cells exist; like as an independent organism, colony and filament. Students were informed of examples of organisms which exist as cell, colony and filament. Using this method for teaching requires that the teacher do all the talking while the students are passive, either listing or copying notes. However, during the lesson the teachers periodically asked questions to find out if the students were following.