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Full Length Research Paper

Which way do we go in the teaching of biology? Concept mapping, cooperative learning or learning cycle?

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The major purpose of this study was to compare the relative effectiveness of concept mapping, cooperative learning and learning cycle methods with the intention of identifying which one among them will be most appropriate for teaching biology. To guide this study, five hypotheses were stated and tested at 0.05 level of significance. The design of the study was pre-test, post-test, follow-up post-test control group quasi experimental design. The sample 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 three instructional methods on achievement and retention; students in the learning cycle and cooperative leaning groups significantly out scored those in the concept mapping group on achievement and retention tests; students in learning cycle and cooperative learning groups did not significantly differ on achievement and retention tests; males and females in all the three groups did not significantly differ on the achievement test; and non significant interaction effect between sex and method of instruction on achievements. It was concluded that the adoption of either learning cycle or cooperative learning strategies will be appropriate for the teaching and learning of biology.

Key words: Concept mapping, cooperative learning, cycle, retention.

INTRODUCTION

There are several perspectives in ways in which pupils learn (Bennett, 2003). Four of these perspectives which have been known to particularly influence science education are: transmission of knowledge; discovery learning; developmental view of learning; and constructivism. The history of science teaching has evolved from the transmission of knowledge approach through discovery approach to constructivism where we are now.

The transmission view of teaching and learning sees teachers as passing over their knowledge to their pupils (Bennett, 2003). This view Bennett noted is strongly linked to expository teaching, where the teachers stand in front and tell their pupils about scientific ideas. The transmission view implies that pupils' role in the learning process is largely passive, and that a pupil's mind is what is sometimes called "tabula rasa"- a blank state onto which knowledge can be written. The limitations experienced with the transmission approach led to the development of other views of science teaching and learning.

Discovering learning involves presenting pupils with information in a form which requires them to discover relationships within the information, and to structure and make sense of the information and relationship (Bennett, 2003). 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, and proponents of this approach argued 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. The school science curriculum which adopted the discovery approach to teaching emphasized the presentation of science to pupils as a way in which they could conduct their own inquires into the nature of things. Discovery learning in science placed a strong emphasis on practical work organized in such a way that pupils made observations, looked for patterns and came up with possible explanation for those patterns.

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 mark over the nature of the understanding pupils developed – left to their own devices, to what extent do 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.

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 (Bennett, 2003; Trowbridge and Bybee, 1996). Constructivist view of learning holds that people construct their own meanings from what they experience, rather than acquiring knowledge from other sources. The impact and development of this view led to the development of different strategies now employed in the teaching and learning of science. Specific examples among constructivist approaches include concept mapping, cooperative learning and learning cycle.

Literature on concept mapping (Turkmen et al., 2005; Cardak and Dikmenli, 2008; Tastan et al., 2008), cooperative learning and learning cycle show 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 which propelled this study with the sole purpose of identifying the most appropriate strategy among them which best suits the teaching and learning of 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 (Trowbridge and Bybee, 1996). The major concern of science education researchers is the identification of the best instructional methods/strategies which will enable all learners to learn effectively. 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 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 (Ajaja, 2009; Bennett, 2003). Ajaja (2011) 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 work of Ausubel and others in the 1970s (Ajaja, 2011). Continuing, Ajaja noted that 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 (Novak and Musonda, 1991; Power and Wright, 1992; Trowbridge and Bybee, 1996; Johnson and Raven, 1998).

Isolated studies from literature 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 students' 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 reviewed the concepts they were assigned to. All the students in the concept mapping classroom interviewed 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 et al. (1992) and Kinchin (2000a, 2000b) are similar to this research finding. Kinchin (2000a) found a significant impact of concept mapping 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. On the effect of concept mapping for attitudinal change, the studies by Markow and Lonning (1998) and Eravwoke (2011) found a significant and positive effect on students' attitude when used for better understanding of chemistry concepts.

Bennett (2003) identified two major limitations of the use of concept mapping in instruction. First, they are 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. These limitations are found to frustrate low achievers in mastering the techniques required for the use.

The cooperative learning approach to instruction is where students are arranged in pairs or small groups to help each other learn assigned material (Trowbridge and Bybee, 1996). Interaction among students in cooperative learning groups is intense and prolonged (Borich, 2004). Unlike self-directed inquiry, in cooperative learning groups, students gradually take responsibility for each other's learning. Trowbridge and Bybee (1996) identified four basic elements in cooperative learning models. These basic elements include: small groups must be structured for positive interdependence, face-to-face interactions, individual accountability, and use of interpersonal and small group skills.

Cooperative learning has been found to be very useful in several areas and prominent among them are: helping learners to acquire from the curriculum the basic cooperative attitudes and values they need to think independently inside and outside the classroom (Johnson et al., 1990); promoting the communication of pre – social behaviour, encouraging high thought processes and fostering concept understanding and achievement. Cooperative learning brings together in adult like settings which, when carefully planned and executed can provide appropriate models of social behaviour (Stevens and Slavin, 1995). Stevens and Slavin (1995), stressing the importance of cooperative learning, noted that if all of the preceding 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 leaner (Bramlett, 1994; Megnin, 1995; Webb et al., 1995).

A review of studies on the effects of cooperative learning on students' achievement indicated that all the researchers made similar discoveries (Ajaja and Eravwoke, 2010). Specifically Ajaja and Eravwoke noted that studies by Stevens and Slavin (1995), Bramlet (1994), Megnin (1995), Webb et al. (1995), Glassman (1989), Johnson et al. (1986) and Crooby and Owens (1993) found that cooperative learning gains are not limited to a particular ability level or sex but to all who engage in it. Study of Stevens and Slavin (1995), for example, linked cooperative learning to increase in academic achievement of learners at all ability levels while studies by Glassman (1989) and Johnson et al. (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 to improve achievement, who had difficulties making success in the traditional classroom.

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

Moyer et al. (2007) noted that the learning cycle model of learning and teaching has 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 who thought of how to apply cognitive development theory and discovery learning to instructional strategies in elementary science. Atkin and Karplus (1962), 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) programme.

There are three phases to the learning cycle: Exploration, Invention, and Discovery and were first used in the SCIS programme (Trowbridge and Bybee, 1996). 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 has evolved through modification to include additional phases such as engagement, exploration, explanation, elaboration, extension and application, and is used to frame single guided discovery lesson as well as extend experiences such as chapters and units. Moyer et al. (2007) noted that a fifth phase, evaluation, was incorporated into an elementary science programme developed by the Biological Science Curriculum Study (Biological Science Curriculum Study, 1992). The learning cycle format adopted in this study is the Bybee's (1997) five steps of Engagement, Exploration, Explanation, Elaboration and Evaluation.

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 Pulat (2009), Cardak et al. (2008), Nuhoglu and Yalcin (2006), Baser (2008), Whilder and Shuttleworth (2004), Lee (2003) and Lord (1999) found that students' achievement improved after the instruction of 5E learning cycle. Specifically, the empirical study by Lee (2003) found 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 mathematics. The results showed that the students' mathematics achievement improved after the instruction of learning cycle. Cardak et al. (2008) determined the effect of 5E learning cycle on primary school students' science achievement. The results showed that the students' science achievement improved after the instruction of 5E learning cycle.

On retention, studies by Ajaja (1998) and Nuhoglu and Yalcin (2006) found that learning cycle enhanced the retention of science knowledge. Nuhoglu and Yalcin specifically emphasized that learning cycle makes knowledge long lasting and that students become more capable to apply their knowledge in other areas outside the original context.

On attitude, literature generally indicated a general improvement in students' attitude when they are taught with 5E learning cycle. Specifically studies conducted by Lord (1999), Whilder and Shuttleworth (2004) and Ceylan (2008) found significant differences in attitude gains between the experimental and control groups in favour of the experimental groups. However, the study conducted by Kaynor (2007) on the effect of 5E on attitude towards science indicated that although there were attitude gains by the experimental groups, the gains were not significant.

From the foregoing, attempt has been made in describing the features of the three instructional strategies currently known to be very effective for science teaching and learning (concept mapping, cooperative learning and learning cycle) with the intention of isolating the most effective one among them for recommendation for the teaching and learning of biology. Specifically this study compared the effectiveness of the three instructional strategies using the parameters of concept understanding measured with achievement score, sex biases of methods and retention of biological knowledge.

Statement of the problem

This study was propelled by the very interesting discoveries from literature that concept mapping, cooperative learning and learning cycle instructional strategies significantly affect students' achievement, attitude and retention of scientific knowledge. This development indicates a significant breakthrough in science education research in the identification and creation of a learning environment where all students can learn equally and effectively too. However, a question may be asked as whether these three instructional approaches will produce the same effects on students in their study of different school science subjects. This is a gap which exists in literature which needs to be filled to enable researchers and science teachers fully appreciate the roles and effects of these three instructional strategies in the teaching and learning of science.

Specifically, comparing biology teaching and learning with these three strategies, the statement of the problem therefore is, will the application of concept mapping, cooperative learning and learning cycle teaching strategies in teaching and learning of biology produce similar effects on students achievement, retention and between males and females?

Research questions

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

1) Is there any effect of the experimental and control methods of instruction on students' achievement?
2) Is there any difference in biology achievement among students taught with concept mapping, cooperative learning, learning cycle, and lecture methods?
3) Is there any difference in biology achievement between males and females taught with concept mapping, cooperative learning and learning cycle?
4) Is there any difference in the retention of biological knowledge among students taught with concept mapping, cooperative learning and learning cycle?
5) Is there any interaction effect between method of instruction and sex on biology achievement?

Research hypotheses

The following null hypotheses were stated and tested at 0.05 level of significance to further direct this study.

$H0_1$: There is no significant effect of the use of concept mapping, cooperative learning, learning cycle and lecture methods of teaching on achievement.
$H0_2$: There is no significant difference in biology achievement among students taught with concept mapping, cooperative learning, learning cycle, and lecture methods.
$H0_3$: There is no significant difference in biology achievement between male and female students taught with concept mapping, cooperative and learning cycle teaching strategies.
$H0_4$: There is no significant difference in the retention of biological knowledge among students taught with concept mapping, cooperative learning and learning cycle teaching strategies.
$H0_5$: There is no significant interaction effect between method of instruction and sex on achievement.

METHODOLOGY

Design of the study

The design used for this study was a 4 x 2 x 3 pre-test, post-test non equivalent control group quasi experimental factorial design. The design consisted of four instructional groups (concept map group, cooperative group, learning cycle group and lecture group), two sexes (male and female) and repeated testing (pre-test, post-test and follow-up test). The independent variable was the instructional strategies while the dependent variables were immediate achievement and retention of biological knowledge. The moderator variable was sex of students.

Sample and sampling technique

The samples of the study consisted of four mixed senior secondary schools, eight biology education graduate teachers who have taught biology for at least five years, eight senior secondary school class II (SS II) science classes, that is, two classes per school and 259 students drawn from 40 public secondary schools in Ika South Local Government Area of Delta State.

The selected schools for the study which was done randomly using balloting were first considered for selection after due consideration of some parameters. The parameters included the presence of well equipped biology laboratory, trained and experienced biology teacher and school must be mixed. To this end, all the single sex schools and schools without laboratories were isolated from the study.

Instruments

Two major instruments were used for the study. The instruments included: (i) A twelve week instructional unit on biology; and (ii) biology achievement test (BAT). The 12 week instructional unit on biology covered the following topics: (1) the cell; (2) diffusion and osmosis, (3) feeding definition and types and cellular respiration, (4) photosynthesis, chemosynthesis, and heterotrophy, (5) excretion, (6) growth, (7) cell reaction to its environment, (8) types of movement, (9) reproduction and (10) tissues and supporting systems.

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. The duration for treatment lasted for that long for the purpose of comprehension of the methods by both teachers and students.

The validity of the biology achievement test was done by a panel of three made of two experienced biology teachers drawn from three public senior secondary schools in Ethiope East Local Government Area of Delta State and an expert in measurement and evaluation. They determined the content validity of the instrument by critically examining the test items and relating them to the content of the 12 weeks instructional units. The panel's approval of the test items as being able to measure what it intends to measure led to the use of the instrument for the study.

To determine the reliability of the instrument, the procedure followed by Ajaja and Eravwoke (2010) in a similar study was adopted. The battery of achievement tests was constructed by adopting a discrimination power capability of the test to discriminate between high and low achievement of 0.3 and 0.7 as being acceptable. All the test items, with discrimination power of below 0.3 and higher than 0.7 were removed and reconstructed. On difficulty level of test items, a difficulty level of between 25 to 80% was accepted. Items with difficulty level of below and above the specified range were removed and replaced. Specifically, the reliability index of the instrument was determined by adopting the Kuder-Richardson 21 formula. This involved the administration of the Biology achievement test (BAT) to 65 SSII biology students in St. Charles College, Abavo, who were not part of the study. On analysis of the test scores using Kuder-Richardson 21 formula, a reliability index of 0.86 was obtained. This proved that the instrument was reliable and thus suitable for the study. The reliability index of 0.86 found perfectly agreed with the established standard as recommended by Thorndike and Hagen (1997), Wiseman (1999), Johnson and Christensen (2000), Borich (2004) and Leedy and Ormrod (2005) 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 characteristics it was designed to measure. With all these findings about the instrument, it was administered on the subjects.

Treatment procedure

The treatment procedure adopted was the combination of three treatment steps used for similar studies: effects of cooperative learning on integrated science students achievement (Ajaja and Eravwoke, 2010); concept mapping as a study skill: effects on students achievement in biology (Ajaja, 2011) and effects of 5E learning cycle on students' achievement in biology and chemistry (Ajaja and Eravwoke, 2012). The eight teachers used as instructors were trained on the skills of using the instructional strategies compared in the study.

Training of instructors

Six of the eight instructors used for the study were trained on the skills of using concept maps, cooperative learning and 5E learning cycle for teaching for four days lasting for two hours per day. Three other specialists on instruction joined the researcher in training the instructors on the skills of concept mapping, cooperative learning and learning cycle. The first day was spent discussing the theories, origins and characteristics of the three instructional strategies (concept mapping, cooperative learning and 5E learning cycle). On the second day, the instructors were trained using the training manuals developed by the researcher; one each for concept mapping, cooperative learning and 5E learning cycle. The instructors for each of the teaching strategies were trained separately by different resource persons. The training manuals specifically defined the steps and stages involved in using concept maps, cooperative learning and 5E learning cycle for teaching, and the specific roles teachers and students play in each stage. The third and fourth days were spent on practice and generation of ideas on how to apply concept maps, cooperative learning and 5E learning cycle 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.

Step by step treatment procedure

The treatment groups consisted of:

a) Experimental groups (concept mapping group, cooperative learning group, and 5E learning cycle groups); and
b) Control group (lecture method group)

A week before the commencement of treatment, all the eight biology instructors used for the study 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 notes written on each of the concepts in the 12 week instructional unit using the concept mapping, cooperative learning and 5E learning cycle teaching formats were given to the specific teachers assigned to use the various instructional strategies for teaching. This was done to ensure that all the instructional presentations followed the recommended format for the designated classes. The lesson notes specified both the teachers and students activities during instruction.

Two days before the commencement of instruction, both the experimental and control groups were pre-tested with the 120 items Biology Achievement Test (BAT). This was done to determine the equivalence of the groups before treatment and be sure that any noticed change later was due to the treatment. On treatment, for the control group, each and all the contents in the 12 week instructional unit were presented to the students using lecture method. The two teachers who taught the control groups presented the content materials to the students in their final forms. In the experimental classrooms where concept mapping, cooperative learning and 5E learning cycle instructional strategies were applied, the following activities were performed.

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 top to down. With these steps_learned and understood, the students practiced the construction of several concept maps before the commencement of instruction.

On treatment, the students taught with concept mapping strategy were asked to read the extracts they were presented and construct a pre – instruction concept map. This was followed with 60 min pre – study instruction on concepts in the various week's instruction. After this, the students did the study, and turned in assignments at the end of every week's instruction. The students in the experimental group 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 experimental group's understanding of the concepts learned in the units of instruction.

Cooperative learning classroom: The students in each group were four. The teachers in 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 et al. (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). 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 cooperation, (11) explain the criteria for success; (12) explain the specific cooperative behaviours; (13) monitor student's work; (14) provide task assistance; (15) teaching collaborative skills; (16) provide closure for the lesson; (17) evaluate the quality and quantity of students' learning; and (18) assess how well the groups function.

5E Learning cycle classroom: In the learning cycle classroom, the teachers who taught there performed the following activities by applying the procedures recommended by Trowbridge and Bybee (1996) strictly. The stages are as follows:

Engagement

Those teachers posed problems to get the students' attention. This was followed by pre-assessing students' prior knowledge on the topics. They went ahead to inform students of the objectives of the lessons. 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 their 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

Table 1. Comparison of pre and post test achievement means of concept mapping, cooperative learning, learning cycle and lecture (control) groups and t – test comparison of pre and post test means.

Group	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
Learning cycle	69	25.45	50.21	68	21.90	1.994
Lecture (control)	59	25.39	36.97	58	9.143	2.00

Table 2. ANOVA Comparison of pre – test scores of concept mapping, cooperative learning, learning cycle and lecture (control) 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				

situations;
ii) Use pervious 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 kinds of questions which 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.

At the end of every two week's instruction a post achievement test of 20 items was administered to both the experimental and control groups. The students test scores were averaged at the end of the 12 weeks of instruction to present a single test score. Four weeks after the post test, a follow-up test using the same instrument was administered to the three groups in the experimental group and the contrast group with the intention of estimating the retention of the knowledge taught after that period of treatment.

Two 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 the control and the experimental groups. Analysis of variance was used to compare the males and females in the three experimental groups on achievement. For paired samples, t – test was used to test for significant difference between students' pre-instructional and post-instructional test scores. Analysis of variance was also used to compare the retention among the experimental groups.

RESULTS

Table 1 showed that on the pre-test scores, all the groups in the experimental and control groups were equivalent on the knowledge of the concepts taught before treatment by mere comparison of their means. This was confirmed with ANOVA test. The ANOVA comparison of the groups as shown in Table 2 indicated non-significant difference F = 2.1752, $P \geq 0.05$. On the post-test scores, Table 1 indicated that students taught with learning cycle scored the highest marks. This was followed by students in the cooperative learning, concept mapping and lecture (control) groups respectively. All the experimental groups scored higher marks than the control group. On the t – test comparison of the pre-test and post-test means, the table indicated significant effects of the experimental and control methods on achievement. With this result, Ho_1 was therefore rejected.

Table 3 which compared achievement test scores of students in the experimental (concept map, cooperative learning and learning cycle) groups and the control group (lecture) indicated a significant difference among the groups. The calculated F was found to be greater than the critical F, which implies that F = 20.557, $P < 0.05$. With this result, Ho_2 was therefore rejected. The post hoc analysis using Scheffe test shown in Table 4, to determine the direction of the noticed significance indicated the following: (i) all the students in the experimental groups significantly outscored those in the control group; (ii) students in the cooperative learning and learning cycle groups significantly outscored those in the concept map group and; (iii) students in the cooperative learning and learning cycle groups did not significantly differ from one another.

In Table 5, the ANOVA comparison of post test scores

Table 3. ANOVA summary table comparing concept mapping, cooperative learning, learning cycle and lecture (control) groups on achievement with pre-test as co-variant.

Source of variation	Type III sum of square	df	MS	F	Sig.
Corrected model	16193.423a	7	2313.346	27.297	0.000
Intercept	11369.407	1	11369.407	134.157	0.000
Pre	8263.709	1	8263.709	97.511	0.000
Method	7296.140	3	2432.047	20.557	0.000
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			

Table 4. Scheffe post – hoc teat to compare the experimental and control groups.

Dependent variable	(I) Method of instruction	(J) method of instruction	Mean difference	Std. error (1-J)	Sig.
		5E learning cycle	-13.42444*	1.92869	0.000
	Lecture group	group concept mapping	-6.63739*	1.96311	0.011
		Cooperative group	-12.62163*	1.94192	0.000
		Lecture group	13.42444*	1.92869	0.000
	5E learning cycle group	Concept mapping	6.78705*	1.88764	0.005
		Cooperative group	.80281	1.86559	0.980
Post-test					
		Lecture group	6.63739*	1.96311	0.011
	Concept mapping	5E learning cycle group	-6.78705*	1.88764	0.005
		Cooperative group	-5.98424*	1.90115	0.021
		Lecture group	12.62163*	1.94192	0.000
	Cooperative group	5E learning cycle group	0.80281	1.86559	0.980
		Concept mapping	5.98424*	1.90115	0.021

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

Groups	N	Male $\bar{X}$	Male (N)	Female $\bar{X}$	Female	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

scores of males and females in concept mapping, cooperative learning and learning cycle groups indicated that the scores of males and females in the various groups are not significantly different. In all the groups, the calculated F values were less than the critical F values. With this finding, Ho_3 was retained because there were really no significant differences in post test scores between the males and females in the various instructional groups.

Table 6, which compared the mean estimated retention of students taught with concept mapping, cooperative learning and learning cycle, indicated that students taught with the 5E learning cycle method retained most of the biological knowledge (90.7%) than those taught with

Table 6. Comparison of $\overline{X}$ scores of groups taught with concept mapping, cooperative learning and learning cycle on retention.

Groups	N	Average	SD
5E learning cycle group	69	90.7	4.77
Cooperative group	67	88.43731	6.55
Concept mapping	64	81.1125	6.14

Table 7. ANOVA summary table comparing students in concept mapping, cooperative learning, and learning cycle on retention.

Source of variation	SS	df	MS	F	P-value	Fcrit
Between groups	8522.108339	3	2840.703	80.6477	1.02E-36	2.640001
Within groups	8982.01892	255	35.22236			

concept mapping and cooperative learning, respectively. In terms of retention, the group taught with 5E learning cycle method was followed by the group taught with cooperative method (88.44%) while the group taught with concept mapping had the least (81.11%). Table 7, which compared whether the noticed differences in retention scores among the students taught with concept mapping, cooperative learning and 5E learning cycle methods were significant, with ANOVA, indicated a significant difference, $F = 48.1174$, $P\ 3.0417 < 0.05$. With this finding, Ho_4 was rejected because the estimated retention of the students taught with concept mapping, cooperative learning and 5E learning cycle was significantly different.

In Table 3, a non-significant interaction effect was found between sex and method of instruction on immediate post – test achievement. This was based on the fact that the calculated F value is less than the critical F value, $F = 0.501$, $P > 0.05$. With this result, Ho_5 was retained because 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.

The major focus of research in science education is to isolate the appropriate methods and strategies which can guarantee effective teaching and cause effective learning by students. A review of literature on instructional methods and strategies indicated that several new methods and strategies are periodically discovered and recommended for science teaching and learning. For each of these new methods convincing proofs of their effectiveness in science teaching and learning are demonstrated. 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 or strategies are most appropriate for teaching the different science subjects. This study, therefore, is not only timely but significant in the sense that 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 three popular methods for effective teaching and learning.

The first finding of the study indicated that all the experimental methods and the control method compared 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 earned were not by chance but is a result of treatment with the prescribed instructional methods. This implied that all the methods compared have the potential to cause learning to take place but at varying degrees, which is the basis for this study. The ability of this study to establish a cause and effect relationship as found, perfectly agreed with the principle of experimental research as recommended by Borich (2004), Johnson and Christenson (2000) and Wiseman (1999). They all stated that in an experimental research, a treatment must be confirmed to be responsible for any difference noticed.

Another finding of this study was a significant difference in achievement scores among the experimental and control 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 subjects' comprehension of the methods of instruction. These may again have translated into influencing subject's scores in the achievement test. The post hoc analysis which indicated that all the students taught with concept mapping, cooperative learning and learning cycle strategies outscored those taught with lecture method suggests that the students in the experimental groups may have been more active in the learning process than those in the lecture group and thus have contributed to their higher achievement scores. This is hinged on the fact that you 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. Bennett (2003) noted that the transmission view implies that pupil's role in the learning process is largely passive, and that a pupil's mind is what is some-times called a "tabula rasa".

The significant 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 of earlier researchers on this same subject matter. For example, studies by Ajaja (2011) and Kinchin (2000a and 2000b) found significant impact of concept mapping when used for instructing secondary school biology students. On cooperative learning, studies by Stevens and Slavin (1995), Megnin (1995), Webb et al. (1995) and Bramlett (1994) linked cooperative learning to increase in academic achievement of all learners. Specifically, the study by Ajaja and Eravwoke (2010), on the effects of cooperative learning on students' achievement, indicated that students in the cooperative group outscored those in the lecture group. Considering the studies on the effectiveness of learning cycle, studies by Pulat (2009), Baser (2008), Lee (2003) and Lord (1999) found that students' achievement improved after the instruction of learning cycle. For example, Pulat (2009), who determined the effect of 5E learning cycle on mathematics achievement, found that students' mathematics achievement improved significantly over the control group after their instruction of learning cycle.

On the noticed significant higher achievement of students taught with cooperative learning and learning cycle over those taught with concept mapping, the limitations ascribed to concept mapping may be the possible explanation for the lower score. Bennett (2003) stated that the limitations include: concept maps are not easy to construct and respondents need a long period of training and practice before its effective use; and there are difficulties with the interpretation of concept maps, and in particular with devising appropriate ways of scoring to enable valid comparison to be made. These limitations may have frustrated the low achievers particularly and resulted in their lower achievement scores to produce the lower mean score for 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 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' learning and understanding of the concepts they were exposed to equally.

This study again found a non significant difference between the males and females in the concept mapping, cooperative learning and 5E learning cycle groups. This finding, therefore, suggests that the three 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 earlier researchers on the same subject matter. Studies by Ajaja (2011), Kinchin (2000a), Hall et al. (1992) and Candan et al. (2006) on concept mapping; Ajaja and Eravwoke (2010), Megnin (1995) and Webb et al. (1995) on cooperative learning; and Pulat (2009), Lee (2003) and Lord (1999) on 5E learning cycle did not report any significant difference in achievement between males and females in the various groups studied. They all reported that learning gains were not limited to any particular sex. The methods used may have influenced the students' understanding of the concepts equally that their achievement scores fell within a close range.

On the estimated retention determined with the follow – up post – test, the study found that students taught with the 5E learning cycle, cooperative learning and concept mapping retained a reasonable percentage of the concept taught after four weeks of initial treatment. As shown in Table 5, the order of retention followed this sequence: 5E learning cycle group (90.7%); cooperative learning group (88.44%) while concept mapping group (81.11%). The ANOVA comparison of the three experimental 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 method. No significant difference was however found on retention between students taught with 5E learning cycle and cooperative learning methods. The finding of significant retention by students in all the instructional groups agreed with what initial researchers found using the various methods. Ajaja (2011), Turkmen et al. (2005) and Kinchin (2000b) found that students who used concept mapping as a study skill retained biological knowledge longer. On cooperative learning, studies by Bramlett (1994), Megnin (1995) and Webb et al. (1995) found that cooperative learning improved critical thinking and reasoning which derive their strength from retention. Study by Nuhoglu and Yalcin (2006) found that learning cycle enhanced the retention of science knowledge.

The noticed lower retention of biological knowledge by students taught with concept mapping than those taught with 5E learning cycle and cooperative learning may not be unconnected with the two earlier identified limitations associated with concept mapping. 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. This 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 engaging students in the learning process in the two strategies. To apply cooperative learning in the biology teaching involves 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.

The study 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 and learning cycle 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 perfectly agrees with the intention and recommendation of science education researchers that whatever method that should be adopted for science teaching should be such that enable students to learn equally irrespective of sex. This finding is most relevant now that there is a deliberate effort to bridge the gap between males and females on representation in science.

Conclusion

The findings of this study indicated that all the three instructional methods compared showed significant effects on students' achievement as measured with immediate post-test and follow – up post test to determine retention. There were however, variations in the levels of achievement among students in the three instructional groups compared. Students in the learning cycle group were found to score the highest marks both in immediate achievement and retention tests. Students in the cooperative learning and concept mapping groups followed respectively. 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 most appropriate methods for teaching and learning biology should be either the learning cycle or cooperative learning. These methods will however be most 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.

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