INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 18, No. 6, p. 258-267, 2021

RESEARCH PAPER OPEN ACCESS

Effects of concept-mapping and inquiry strategies in teaching difficult curriculum concepts in biology on students' academic achievement and retention

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Key words: Concept-mapping, Inquiry, Difficult, Achievement and retention

http://dx.doi.org/10.12692/ijb/18.6.258-267 Article published on June 30, 2021

Abstract

This study determined the effects of concept mapping and inquiry method in teaching difficult curriculum in secondary school Biology on students' academic achievement in Delta State. The study adopted non-randomized pre-test, post- test, control group quasi experimental design and a 3×2×2 factorial design using three research questions and hypotheses. The population consisted of all senior secondary school II (SS II) biology students in Delta South Senatorial districts of Delta state with two hundred and fifty-one (251) students were drawn from six classes. The instrument used was the Biology Achievement Test (BAT) for data collection. Face and content validity of the instrument was ascertained by three experts. The reliability was determined using Kuder-Richardson 21 formula to obtain a reliability coefficient of 0.75. Analysis of Covariance (ANCOVA) and t- test, tested at 0.05 level of significance, mean and standard deviation, were used to analyze the data. The result of the study showed a significant difference between the performance of students exposed to the two experimental groups (Concept-Mapping and inquiry methods) and the control group (lecture method); there was no significant difference in achievement test scores between male and female students taught difficult topics in biology using Concept-Mapping and inquiry; the level of retention was higher with students taught with concept-mapping than those taught with inquiry strategy. Based on the findings, it was concluded that Concept-Mapping will be a suitable method for teaching difficult concepts in biology. It therefore recommends that biology teachers should be retrained on application of Concept-Mapping in biology teaching.

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Introduction

The teaching of science is by no means a simple task. Its learning on the part of the learners depends on the way it is presented and the way the learner actively interacts with the learning experience. Biology is one of the science subjects taught in Nigerian schools. It is the science of life offered in all the senior secondary schools which attracts the greatest patronage of both science-oriented and arts-based students, Nwosu, (2006). Biology is integral in content provision for science subject in training students to study courses such as biochemistry, fisheries, forestry, medicine, nursing and pharmacy. The content of the curriculum is spirally arranged to include concept of living and ecology, nutrition in plant and animal, variations and variability as well as genetics and evolution.

The contents of the Biology curriculum place emphasis on Field studies, Guided Discovery, Laboratory techniques and skills. The cardinal objectives according to FRN (2004) are to prepare students to acquire adequate skills in laboratory and field biology, knowledge relevant in biology, Ability of applying scientific knowledge to life in matter of personal and community health and agriculture, and reasonable and functional scientific altitude.

The intent of biology curriculum according to Agu (2006), has been adjudged laudable. However, there are evidences that, though students find biology interesting ans register it in large number at the Senior Secondary School, performance remain poor (Okebukola and Akinbola, 2008). Although, efforts are being made by the Government, researchers, and science educators to improve the teaching and learning of biology, achievement in the subject continues to be poor. Researchers attributed this trend of poor performance to biology teachers who emphasized theoretical presentation of biology concepts at the expense of practical and the use of ineffective teaching strategies. Also, research findings showed thatstudents find some concepts in biology difficult to learn and answer in examinations leading to poor performance of students at Senior School Certificate Examination (SSCE).

Cimer (2011) argued that many concepts in Biology including matter transport in plant, protein synthesis, genetic engineering, mitosis and meiosis are difficult to learn. Umeh, (2002); Makanjuola (2002) identified hormonal co-ordination while Esiobu and Soyibo (1995); and Umeh (2002) identified evolution, genetics and ecology as difficult aspects of secondary school biology. This was buttressed by the WAEC Chief Examiners yearly reports of 2000, and 2004 indicating that biology candidates lack the knowledge of basic concepts in biology and exhibit weakness in answering questions relating to difficult concepts. Such weakness induces students' inability to comprehend or represent concepts in tables, graphs and diagrams. Ozcan (2003) stressed that experiencing difficult topics negatively affect student motivation, and achievement. Student's difficulty in biology topics have stimulated researchers to investigate why student experience such difficulties. This could be attributed to abstractness, complexity, misconception of topics, unavailable instructional materials, poor attitude of teachers to teaching, lack of practical classes, poor student habits, overloaded curricular content and delineation of science from society (Zeidan, 2010; Cimer, 2004). Another possible reason is that due to the nature of biological science, biology learning is general based on memorization. This make it hard for students to learn (Saka, 2006, Durmez, 2007)

It is clear that when concepts are not meaningfully understood by students, they tend to skip questions from such areas in the Senior Secondary Certificate Examination (SSCE), leading to poor performance. These re-occurring reports of poor performance of students at SSCE biology have called for concern from science educators. At such, science education research in seeks continuous ways to improve the teaching of Biology in Nigeria to maximize learning outcomes and identify factors responsible for repeated failure, Esiobu, (2000) Ajaja and Kpangban, (2000). Teaching is effective when the approach used brings about a desirable change in the behavior of the learner. If learning strategies and students' achievement have to improve, then the students have to be introduced to more innovative and efficient

teaching strategies, such as inquiry, and concept-mapping which have proved effective than the lecture method dominantly used in schools. Concept-Mapping is a pedagogical/metacognitive tool designed to help students learn how to learn, Novak. It was developed from Ausubel, (1968) assimilation theory of cognitive learning. Concept mapping according to Ossai, (2004) is a graphical arrangement of key concepts to show meaningful relationship among concept or ideas been studied. It provides a visible means of connections, relating a hierarchy of ideas raging from the concrete to the abstract (Ajaja, 2009; Bennett, 2003). The history of development of concept mapping as an instructional tool can be traced to the early work of Ausubel and others and it has become a useful tool in the teaching and learning particularly in science education research. Concept mapping help students learn about their knowledge structure and the process of knowledge construction. It encourages students to learn difficult concepts. However, it has been scanty in the biology classroom especially in the teaching of difficult concepts.

Inquiry approach on the other hand is a student-centered, activity-oriented teaching strategy in which the teacher guides learners through problem-solving approach to discover answers to problem (Azubuike, 2005). It provides students the opportunity to find out facts and ascertain reasons why things are the way they are. The learner puts things together for himself, discovered facts, while the teacher acts as a catalyst. It exposes the learner to discover knowledge. Inquiry method permits the learner to observe an event, recognize a problem, analyze the variables, recognize relevant and irrelevant questions, search out data and take complete responsibility for an entire process of obtaining, organizing and interpreting data.

It exposes learner to discover knowledge. Nwagbo (2001), Nweke (2004) and Azubiuke (2005) noted that the guided inquiry method has proved significantly better in enhancing cognitive achievement, promote critical thinking based on creativity. In this study, sex is considered. Sex refers to the biological and psychological characteristics that define men and women; male and female are sex categories (Prince, 2005). Therefore, sex in this study refers to male and female biology student. Sex issue in science education has remained a point of interest for a number of researchers.

It was emphasized that despite the high performance of boys in most countries, girls seem to portray weaker self-concept in science subject including biology (on the average they had lower levels of belief in science). Yet, both boys and girls are similarly interested in science; and there is no overall difference in boys and girls inclination to use science in future study (Eu, 2010). Literature shows mixed result on the effect of sex on student academic achievement. This opposing opinion is one of the rationales for this study. Hornby (2000) define retention as the ability to remember experiences and learnt content. Retention is measure in collaboration with achievement which encompasses the ability of the student to apply knowledge from lesson in particular situation as a function of recall and conceptualization (Seifert, 2012). Empirical studies have shown that innovative strategies (Concept-mapping and inquiry among others) improve student's retention (Alake, 2015). It was purely in an attempt to bridge the gap on the knowledge of the effects of concept- mapping and inquiry on student's achievement and retention in biology that this study was carried out. The general objective of the study was to determine the effects of concept mapping and inquiry method in teaching difficult curriculum in secondary school Biology on students' academic achievement in Delta State. Specifically, the study (a) compares the relative effectiveness of two instructional methods in teaching difficult curriculum concepts in biology, the concept-mapping and the inquiry and to identify which of the two methods was more effective, (b) find out if there is any difference in students' achievement test scores between male and female students taught difficult curriculum concepts in biology using concepts-mapping, inquiry and lecture methods and (c) attempt to find out if there is any difference in the retention level of students taught difficult curriculum concepts in biology using concept-mapping and inquiry strategies.

Materials and methods

The design of the study was the quazi-experimental design using pretest, post-test control group with three intact classes of 67,101 and 83 biology students respectively to provide for stability and to avoid disruption of class lessons and arrangement. The population consisted of all Senior Secondary School II (SS II) Biology students from Delta Central Senatorial District of Delta State. The sample consists of two hundred and Fifty-one (251) Biology students from three public mixed senior secondary schools. This consisted of one hundred and thirty (130) males and one hundred and twenty (120) females.

Research Questions

The following research questions were raised to guide this study:

1. Is there any difference in achievement test scores between students taught difficult curriculum concepts in biology using concept-mapping, inquiry, and those taught using the Lecture method?
2. Is there any difference in achievement test scores between male and female students taught difficult curriculum concepts in biology using concept-mapping, inquiry and lecture methods?
3. Is there any difference in the retention level of students taught difficult curriculum concepts using concept-mapping, inquiry and lecture method?

Research Hypotheses

The following hypotheses were stated and tested at the 0.05 level of significance:

Ho_1 There is no significant difference in achievement test score among students taught difficult curriculum concept in biology using concept-mapping, inquiry and the lecture methods.

Ho_2 There is no significant difference in achievement test scores between male and female students taught difficult curriculum concepts in biology using concept-mapping, inquiry and lecture methods.

Ho_3 There is no significant difference in retention level among students taught difficult curriculum concepts in biology using concept-mapping and inquiry.

Instrumentation

The instrument used for the study was the Biology Achievement Test (BAT) which contained fifty multiple choice test questions with four options (A, B, C D & E). BAT was constructed on the following difficult curriculum concepts in biology: Transport system; protein synthesis, genetic engineering, mitosis and meiosis, hormonal coordination. BAT also was used to measure student's retention in Biology. The retention test was designed by reshuffling BAT in the serial arrangement of the question and the answer options.

Validity and Reliability

BAT was subject to both content and face validity by 3 experts in Science Education, Measurement and Evaluation and one biology teacher that has taught biology for at least five years. These experts examined the content to ascertain if the instrument could be used effectively. Their comments and suggestions were used to produce the final draft for the study. The reliability of BAT was established using the Kuder-Richardson 21 formula. The choice of this approach was that it is appropriate for multiple options objective test items. The instrument was pilot tested to 30 Biology students outside the area of coverage for the study. Data obtained were subjected to Kuder-Richardson 21 formula. On correlation, a reliability coefficient index of 0.75 was obtained which met the standard as specified in Borich (2004) and Leedy and Ormrod (2005).

Treatment Procedure

i. Training of research assistants: The researcher sought the approval of the school heads in order to use the teachers and students in the selected schools. The teachers were trained on the skills using the concept-mapping and inquiry approaches to teach these identified curriculum concepts in biology. This lasted for 3 days and on the last day of the training, the trained research assistants were given instructional package which consist of a comprehensive of a lesson plans and four-week instructional units.

ii. Treatment: The First step in the treatment procedures is the assignment of students into experimental (Concept-mapping and inquiry strategies) and control group (lecture strategy). Two intact classes made up the experimental group, while the other intact class served as the control group. Both the experimental and control groups were exposed to the same difficult topics in Biology and learning environment. While the experimental groups were taught using concept-mapping and inquiry strategies, the control group used the lecture strategy. The treatment lasted for four weeks. Before the commencement of treatment, both the experimental and control groups were pretested with the 50 items of Biology Achievement Test (BAT). This was done to ascertain the equivalence of the groups before treatment and be sure that any noticed change later was due to the treatment. A day after the end of the treatment, BAT was administered to both the experimental and control group as posttest. After three weeks, BAT was administered again as follow-up test (Retention). The pretest, posttest and follow-up test scores for each group were collated and analyzed.

Method of Data Analysis

Data were analyzed using mean, standard deviation, t-test and ANCOVA tested at 0.05 level of significant.

Results

Table 1. Mean and standard deviation of the students taught using Concept-Mapping, Inquiry and the Lecture Methods.

Treatment Groups	Mean	N	Std Deviation
Inquiry	56.19	67	11.16
Concept-Mapping	62.07	101	14.60
Lecture Method	36.36	83	4.87

Table 1 shows the mean and standard deviation for the three types of instructional strategies used in teaching difficult topics in biology on students' achievement. Students taught using concept-mapping had a mean score of 62.07, followed by students taught by inquiry with a mean score of 56.19 while the lecture which served as control had a mean score of 36.36.

The above table indicates a significant difference among the subjects in the two experimental and control groups. Since the calculated F value of 124.60 is greater than the critical F-value of 3.04 (F = 124.60 < 0.05), the null hypothesis is therefore rejected because there is a significant difference among the instructional groups.

To indicate the direction of the difference, a post-hoc analysis using the Scheffe test was carried out.

Table 2. ANCOVA summary table of Differences among students taught difficult topics in Biology using Concept-Mapping, Inquiry and Lecture Methods.

Sources of Variation	Sum of Square	Df	Mean Square	F	Sig.
Corrected Model	31943.89	3	10647.96	84.11	.000
Intercept	16203.37	1	16203.37	127.99	.000
Pre-test	226.04	1	226.04	1.79	.183
Treatment	31545.82	2	15772.91	124.60	.000
Error	31268.11	247	126.592		
Total	741916.00	251			
Corrected Total	63212.00	250			

a R Squared=.505 (Adjusted R Squared=.499 F critical=3.04 p<.05

Table 3. Scheffe Test to determine the direction of the difference of instructional methods on students' achievement in Biology.

N Subset for alpha= 0.05				
Treatment Group	1	2	3	1
Lecture	83	36.3617		
Inquiry	67		56.1940	
Concept-Mapping	101			62.0693
Sig.		1.000	1.000	1.000

The table shows the Scheffe Test for the three instructional methods on students' achievement in Biology. Students taught with Concept-Mapping performed significantly better than those taught by Inquiry method and Lecture method having contributed 62.07 to the noticed difference as against 36.34 and 56.19 respectively.

The post hoc analysis to determine the direction of significance at 0.05 level of significance indicates the following:

- A significant difference between Concept-Mapping and Inquiry in favour of Concept-Mapping.
- A significant difference between Inquiry and Lecture Method in favour of Inquiry Method.
- A significant difference between Concept-Mapping and Lecture Method in favour of Concept-Mapping.

This finding indicates that among the experimental groups, Concept-Mapping group did significantly better than the Inquiry group who were in turn better than the lecture method. All the experimental groups were found to be significantly better than the control group (lecture method).

Table 4. Mean and Standard Deviation of Achievement between male and female students taught difficult topics in Biology.

Treatment Group	Sex	Mean	N	Std. Deviation
Inquiry	Male	60.48	31	8.77
	Female	62.07	36	14.60
Concept-Mapping	Male	60.56	50	16.06
	Female	63.55	51	13.01
Lecture Method	Male	36.12	49	4.6
	Female	36.71	34	5.18

The table showed the mean score for the male and female students taught difficult topics using Inquiry andConcept-Mapping. The male students taught by Inquiry method had a higher mean score (60.48) than the female students (62.07). For those taught byConcept-Mapping, the female students had a mean score of 63.55, while the male students had 60.56. Lecture method group had a mean score of 36.12 for male, and 36.71 for female.

Table 5. t-test summary table of mean difference in achievements scores between male and female students taught difficult topics in biology using Concept-Mapping.

GROUP	N	Mean	S.D	DF	t-value	t-crit	Level of sig	Decision
Concept-Mapping								
Male	50	52.84	10.89	99	1.32	1.99	0.05	No Significant difference
Female	51	55.73	11.13					

Table 6. t-test Analysis summary table of mean difference in achievements scores between male and female students taught difficult topics in biology using inquiry method.

Group	N	Mean	S.D	DF	t-value	t-crit	Level of sig	Decision
Inquiry Method								
Male	31	52.84	7.15	65	1.39	2.00	0.05	No Significant difference
Female	36	50.00	9.18					

The table shows that the t-calculated value of 1.32 is less than the t-critical value of 1.99. Hence the null hypothesis was retained. This indicate that there was no significant difference in the achievement test scores between male and female students taught difficult topics in biology using concept-mapping. The table shows that the t-calculated value of 1.39 is less than the t-critical value of 2.00. Hence the null hypothesis was retained. This indicate that there was no significant difference in the achievement test scores between male and female students taught difficult topics in biology using inquiry method. Table 7 indicated that students taught with Concept-Mapping had a mean score of 54.3, Inquiry 51.3 while Lecture had mean 34.92. This indicated that students taught with concept-mapping retained more of the learnt material followed by the Inquiry and Lecture methods.

Table 7. Mean and Standard Deviation of Retention level of students taught with Concept-Mapping, Inquiry and lecture methods in the Follow-up test.

Treatment Groups	Mean	N	Std Deviation
Inquiry	51.3	67	8.4
Concept-Mapping	54.3	101	11.1
Lecture	34.9	83	4.3

Table 8. ANCOVA summary table of Difference in Retention Level between students taught difficult topics in Biology using Concept-Mapping, Inquiry and lecture methods.

Sources of Variation	Sum of Square	Df	Mean Square	F	Sig
Corrected Model	18991.01	3	6330.34	86.44	.000
Intercept	13865.26	1	13865.26	189.32	.000
Pre-test	248.03	1	248.03	3.39	.067
Treatment	18646.05	2	9323.03	127.30	.000
Error	18089.88	247	73.24		
Total	593704.00	251			
Corrected Total	37080.00	250			

aR Squared=.512(Adjusted R Squared=.506) F critical=3.04 P<.05

Table 8 shows that the calculated F–value is 127.30 while the table value (F- critical) is 3.04. Since the calculated value is greater than the table value, the null hypothesis is rejected. This implies there was a significant difference in retention level between students taught difficult curriculum concepts in biology using concept-mapping, inquiry and lecture methods. To indicate the direction of the difference, a post hoc analysis using the Scheffe test was computed.

Table 9. Scheffe Test to determine Retention level Between students taught difficult topics in Biology using Concept-Mapping, Inquiry and lecture methods.

		N subset for alpha=0.05	
Treatment Groups	1	2	3
Lecture	83	34.9157	
Inquiry	67		51.31
Concept-Mapping	101		54.29
Sig		1.000	0.089

Table 9 shows that students taught byConcept-mapping retained more material than those taught with Inquiry, while students taught with Inquiry retained more material than those taught by Lecture method. This implies that students taught byConcept-mapping have high retention level compared with students taught by Inquiry and lecture methods having contributed 54.29 as against 51.31 and 34.92 respectively. The post hoc analysis to indicated the direction of the difference at 0.05 level of significance indicates the following:

- A significant difference between Concept-mapping and Inquiry in favour of Concept-Mapping.
- A significant difference between Inquiry and Lecture Method in favour of Inquiry Method.
- A significant difference between Concept-Mapping and Lecture Method in favour of Concept-Mapping.

Discussion

One major finding of this study is that students taught using concept-mapping scored higher marks in biology achievement test than those taught using inquiry and lecture strategies. The result indicated that the group taught using Concept-Mapping performed significantly better than those taught using Inquiry and Lecture methods. This implies that Concept-Mapping strategy proved effective towards enhancement of student's idea and facilitating a better understanding of difficult biology concepts. This finding is in agreement with Okafor and Okeke (2006) and Asishana (2010) who concluded that Concept-Mapping is significantly a useful instructional technique for increasing meaningful understanding of difficult concepts. Jegede, Alaiyeimola and Okebukola (1990) revealed that students who were taught using Concept-Mapping strategy scored higher than their counterparts taught using lecture method. They found that Concept-Mapping reduced anxiety and enhances achievement in biology. Akinsola and Awofala (2004) also gave credence to Concept-Mapping strategy in promoting achievement while researchers, Bajah and Asim, (2002) Madu, (2004) Moemeka, (2002) confirmed that appropriate teaching method such as Concept-Mapping leads to students improved achievement in biology.

There was no significant difference in achievement test score between male and female students taught difficult topics in biology using Concept-Mapping and inquiry methods. The result is in agreement with the findings of Nsofor (2004), Gambari (2010) and Olowe (2010) who reported that biology instructional models affect male and female students equally.

Also, the findings of Lagoke, Jegede and Oyebanji, (1997) Awolanti and Abimbola, (1997) reported no significant difference in male and female students' achievement in the sciences. This result of no significant difference in terms of gender and achievement could be as a result of the innovative instructional approaches adopted by the researcher who discovered that difference in the achievement of male and female students could be taking care of using good methods, materials and appropriate teaching strategies. However, the result contradicts the opinion of Njoku (2000) and Adebola (2004) who asserted that females performed poorly relative to boys in science subjects. Thus, it can be deduced that the use of Concept-Mapping and inquiry methods enhanced male and female students' achievement. Dada (2000), stated that a teacher has the ability of choice in terms of method of teaching once he/she trust the efficacy of such method towards achieving the aims and objectives. In line with this, Oxford (2001) posed that through appropriate planning, any teacher could integrate skills using appropriate methods that will enable him/her achieve his objectives irrespective of sex.

Finally, there was an indication that the level of learning was higher with students taught with concept-mapping than those taught with inquiry and lecture strategies. Brunner (1961) noted that what is crucial in learning are storage of knowledge and retrieval. Hence, the greater the student's involvement, the greater the learning and the level of retention. This finding agrees with that of Alake (2015) who reported that students exposed to innovative instructional strategies retained the learnt content than their counterpart exposed to conventional strategy.

Conclusion

Result from the findings indicated that the concept-mapping strategy was more effective and superior to the inquiry strategy in improving students' achievement in biology. It can be concluded that concept-mapping will be a suitable method for teaching difficult topics in biology in schools since students taught with concept-mapping apart from obtaining high scores also retained more content materials than students taught by the inquiry strategy. Also, sex had no significant difference in achievement between male and female. This means both males and females benefited significantly from the concept- mapping and inquiry strategies.

Recommendations

Based on the findings of this study, the following recommendations were made;

1. Biology teachers should incorporate Concept-Mapping as one of the methods used in teaching biology especially difficult curriculum concepts since the method has the potentials of positively influencing biology teaching and promoting students' academic achievement.
2. Policy makers in the Ministries of Education and Principals of secondary schools should lend full support to make the method a reality.
3. Curriculum planner, developers and science educators should take cognizance of this method (Concept-Mapping) and other innovative pedagogical strategies. Apart from the expansion of the curriculum content, there is need to review the biology curricular in order to have an adequate spread in imparting relevant skill for students to engage in Concept-Mapping.

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