# BIOLOGICAL SCIENCE INQUIRY MODEL: A PRODIGY TO STUDENTS' COGNITIVE ACHIEVEMENT IN BIOLOGY

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**Abstract**
The study investigated the effect of Biological Science Inquiry Model of Teaching on secondary school students' cognitive achievement and retention in biology. Two hypotheses tested at 0.05 level of significance guided the study. The design adopted for this study was Koksal's Randomized Five-group Experimental Design for Science Education Studies (KRFEDSED) with 185 Senior School Students selected randomly from one senior secondary school in Adamawa state, Nigeria. Instrument used for data collection was a cognitive achievement test tagged Biology Cognitive Test (BCT) adapted from WAEC tests from 2012 to 2014. The instrument was content validated by three experts and test-retest method was used for testing its reliability. The reliability coefficient of 0.82 was obtained. The treatment lasted for eight weeks and data were analyzed using two-way Multivariate Analysis of Covariance (MANCOVA). The result revealed that, Biological Science Inquiry Model enhanced students' cognitive achievement as well as retention in biology at both post test and retention test. Furthermore, there was significant difference between male and female students in the experimental group in favour of male students at post test level only. It was recommended that, Biological Science Inquiry Model should be incorporated in the teaching of biology for meaningful learning and that workshops should be organized for pre-service and practicing teachers on how to use Biological Science Inquiry Model.

**Keywords:** BSIM, Gender, Achievement, Retention, Biology

## 1. INTRODUCTION

Several innovative teaching methods were recommended to improve students' achievement in biology, but up to this time, these innovative methods of teaching did not solve the problem of students' poor academic achievement in biology (Sakiyo & Waziri, 2015a). Biology as a subject in secondary school, had witnessed a high enrolment rate compared to any other science subject in the final year external examinations (Oguzor & Opara, 2011). Contrarily, there has not been a corresponding increase in students' academic achievement in the examinations. The output of students' final year academic achievement has been consistently low as revealed by the following 2012-2014 May/June Senior Secondary Certificate Examination (SSCE) results.

**Table 1.Summary of WAEC Results from 2012-2014**

| Year | A1-C6 | D7-F9 |
|---|---|---|
| 2012 | 38.81% | 61.19% |
| 2013 | 36.57% | 63.43% |
| 2014 | 31.28% | 68.72% |

*Source: chief examiner's report 2014.*

Several studies have investigated the causes of the appalling state of students' performance in biology in secondary schools. These causes were identified as; non-availability of biology text books, students' attitude towards biology, non-availability of laboratory apparatus and other learning resources (Samikwo, 2013). Suman (2011) reported parents' occupation as another factor influencing students' academic achievement in biology. Femi and Adewale (2012); Akinsanyo, Ajayi and salomi (2014) identified educational qualification of parents as significant factor affecting students' academic achievement in biology. While, Yusuf and Adigun (2011) reportedthat, gender imbalance in biology is the cause of appalling poor students' academic achievement.

Gender imbalance permeates any aspect of academic endeavor including biology. According to many studies males have higher academic achievement in biology than females (Johnson, 2001; Simpson and Oliver, 2005; Okigbo and Okeke, 2011). On the other hand, Weinburgh and Englehard (1994) found out that, females had better academic achievement in

biology laboratory than males. While, Sakiyo and Waziri ($2015_a$) found no significant difference on students' achievement based on gender. Sakiyo and Waziri ($2015_b$) recommended that, gender differences can be eliminated when teachers used certain teaching strategies that can bring about gender equity in biology education.

But, various researchers such as Thoros and Myers (2009); Ozdilek and Bulunuz (2009); Oguzor and Opara (2011); Striclyn(2011); Edingyang and Ubi(2012); Ali, Toriman & Gosim, (2014); Abdi (2014) & Njoroge, Changeiywo & Ndiregu (2014) attributed the poor academic achievement of students in Senior Secondary Certificate Examination (SSCE) to ineffective methods of teaching biology. Shamnad (2005) reported that even the best curriculum and the most perfect syllabus remain dead unless quickened to life by the right methods of teaching. For many decades innovative teaching methods such as concept mapping, inquiry, Science Technology Society, constructivist etc were tested on students' achievement, but yet the students' achievement is still not appreciable. However, due to the ineffectiveness of teaching methods to solve the problem of poor academic achievement as reported earlier researchers are expected to shift their weight from teaching methods to models of teaching.

A Model of Teaching according to Joyce and Weil (2003) is a description of the learning environment. It is a plan or pattern, which can be used to shape curricula, to design instructional materials and to guide instruction in the classroom and other settings. Models of Teaching have great potentiality for developing the cognitive, affective and psychomotor behaviour of the learner in a balanced and integrated fashion (Shamnad, 2005). A Teaching Model can be considered as a type of blueprint for teaching. It provides structure and direction for teaching. Models of Teaching afford a lively and provocative introduction to the complexity of teaching (Joyce and Weil, 1972).

There are many Models of Teaching that are built around the mental process as ranging from systems for teaching general problem solving ability to procedures for teaching process. Joyce and Weil (1980) have identified 23 models which are classified in to four basic families based on the nature, distinctive characteristics and effects of the models. These four families are:

1. Information processing model
2. Personal model
3. Social interaction models

4. Behavioral modification models

Joyce and Weil (1980) further classified information processing model into seven and they all focus on intellectual capacity. They are concerned with the ability of the learner to observe, organize data, understand information, form concepts, employ verbal and nonverbal symbols to solve problems. The primary purposes of these models are:

a. The mastery of the method of inquiry
b. The mastery of academic concepts and facts
c. The development of the general intellectual skills such as the ability to reason and think more logically

The models under information processing family are

i. Concept attainment model
ii. Taba inductive thinking model
iii. Advance organizer model
iv. Inquiry training model
v. The memory model
vi. Cognitive growth model
vii. Biological science inquiry model (BSIM)

Siddiqui (2013) opined that, the aim of the Biological Science Inquiry Model (BSIM) of teaching is to make the teaching process for the students to process information with the help of various techniques as used by the biologist in their research work. In this area, the research biologists try to identify different problems and apply a specific methodology for solving the problems. BSIM originated from the work of Joseph J. Schwab. Siddiqui (2013) quoted Joseph J. Schwab who said that "the problems created by growing human populations, by depletion of resources, by pollution, by regional developments and the like all require intelligent government or community action. These are, in part at least, biological, ecological problems and every citizen should have some awareness of their background". Further, he stated that "the essence then of a teaching of biology as inquiry, would be to show some of the conclusions of biology in the framework of the way they arise and are tested. This would mean to tell the student about the ideas posed and the experiments performed to indicate the data. Thus found, and to follow the interpretation by which these data were converted into scientific knowledge".

Joyce and Weil (2003) suggested that, there are several techniques which are applied in teaching of biology as inquiry through BSIM. These are as follows:-

First: using Statements

This technique the teacher utilizes several statements which tell about the tentative nature of biology as under:

i) We do not know

ii) I have not been able to find out how this happens

iii) The information about this is contradictory.

Second: Using Narrative of Inquiry

In this technique, the teacher presents the history of major ideas related to biology, explains them and the course of inquiry in this area is followed.

Third: Arranging Laboratory Work

The teacher makes the arrangement of laboratory work. The students are induced to find out various problems. Joseph J Schweb said that or they (Scientists) treat problems for which the text does not provide answers. They create situations in which the students can participate in the inquiry".

Fourth: Designing Laboratory Programme

In this technique the teacher designs laboratory programmes in several blocks. The students are involved in an investigation of a real problem related to biology. At first students may be presented with materials already familiar to scientists and problems whose solutions are already disclosed, but as Schwab said that "as the series of problems progresses they come nearer and nearer to the frontier of knowledge".

Fifth: Using Invitation to Enquiry

In this techniques, the teacher uses "invitation to inquiry". As the laboratory works, the students are encouraged to involve in "invitation to inquiry". Invitation to inquiry induces the students to take active parts in reasoning based activities of inquiry in laboratory or outside the laboratory as the case may be in the area of biology. Rather than being a knowledge fountain, let students wrestle with problems or puzzles and helping students to derive hypotheses and make discoveries, let students make mistakes and research for themselves among plentiful resources. For instance, offer a range of options and ask students which is the best one and why. Students

work out logistics and criteria for selection together or solo and get critique of preferred solution from the teacher.

However, over the cause of this research the researcher searches for many literature but the researcher never encountered with any study conducted in this areain Nigeria, hence the justification of the study.

### **1.2** *Statement of the Problem*

A lot of innovative teaching methods including guided discovery, co-operative learning, science-technology-society, analogy, constructivist, programmed instruction, concept mapping have been suggested for teaching biology, but records show that there is still a trend of poor academic achievement by secondary school students in biology. Nevertheless, no much effort was made towards finding out the effect of models on students' achievement in biology. This compelled the researcher to investigate the effect of Biological Science Inquiry Model (BSIM) on secondary school students' cognitive achievement and retention in biology.

### **1.3** *Research Objectives*

The main objective of the study is to:-

1. Determine the effect of biological science inquiry model on students' cognitive achievement and retention in biology when taught with BSIM and lecture method of teaching.
2. Determine the effect of gender on students' cognitive achievement and retention in biology when taught with BSIM and lecture method of teaching.

### **1.4** *Hypotheses*

Two hypotheses were stated and tested at 0.05 level of significance

**$HO_1$**. There is no significant difference between BSIM group and lecture group on students' cognitive achievement and retention in biology

**$HO_2$**. There is no significant difference between male and female students' cognitive achievement and retention in biology when taught with BSIM

## 2. METHODOLOGY

The research design adopted for this study was Koksal's Randomized Five-group Experimental Design for Science Education Studies (KRFEDSED). KRFEDSED is a true experimental design in which the students are randomly assigned to five groups. Random assignment gives advantages over preventing problems regarding external validity and non-equivalent groups in an experimental study (Currie, 2001). The design has two experimental and three control groups and pre- and post-test applications for two times in three groups.

**Table 2: Diagrammatic Representation of the Design**

| Groups | Randomization | Pre-test | Treatment | Post-test |
|---|---|---|---|---|
| 1 | (Exp group) | $O_1 - O_2$ | X | $O_3 - O_4$ |
| 2 | (control group) | $O_5 - O_6$ | | $O_7 - O_8$ |
| 3 | (Exp group) | | X | $O_9 - O_{10}$ |
| 4 | (control group) | | | $O_{11} - O_{12}$ |
| 5 | (control group) | $O_{13} - O_{14}$ | | $O_{15} - O_{16}$ |

a. Students are randomly assigned into the five groups,
b. two control groups and one experimental group take a pre-test,
c. the groups taking the pre-test take the pre-test again two weeks later (Lin et al., 2007) this was used to determine the reliability of the instrument using test-retest method,
d. two experimental groups are exposed to biological science inquiry model of teaching, while the three control groups are exposed to lecture method
e. all of the groups take post-test,
f. the groups taking the post-test re-take the post-test two weeks after.

The design according to Koksal (2013) is powerful to overcome subject characteristics effect, maturation, history, mortality, subject attitude and regression effects. The study was conducted in Adamawa State, Nigeria. The target population of the study was all Senior Secondary two (SSII) students in senior secondary schools in Adamawa state offering biology. Purposive sampling technique was used to select Government Day Capital Schoool, Jimeta-Yola. The school was chosen for the study because of the large population, co-educational and having only one science class at SSII level with up to 185 (102 males and 83 females) students which

was enough to be divided into five groups, the students were randomly assigned to five groups A, B, C, D, E. Each group consisted of 37 male and female students. All the five groups were taught using BSIM and Lecture of teaching. The experimental group (A and C) consists of 74 (44 males and 30 females) students while, the control group (B, D and E) consists of 111 (58 males and 53 females) students. The instrument for data collection was Cognitive Test tagged the "Biology Cognitive Test" (BCT). The BCT had 60-items multiple-choice objective test items with four options. The instrument was adapted from West African Examination Council (WAEC) biology past questions from 2012-2014. The items covered six cognitive domains of educational objectives (Knowledge contains 25% of the items, comprehension 25%, application 15%, analysis 15%, synthesis 10%, while evaluation takes 10%). The instrument was content validated by three biology teachers. The reliability of the instrument was determined using test-retest method in which the instrument was administered twice at pre-test level as one of the requirements of the design, 0.82 reliability coefficient was obtained. The first pre-test was administered in the first week of the research exercise to the two control and one experimental groups, the groups re-take the pre-test after two weeks before the treatment started. The data were collected by randomly assigned two research assistants (female and male) after thorough training by the researcher; both the research assistants have B. Tech (Ed) biology qualification with at least 5-years working experience. Post-test was administered to all the five groups after six weeks of instruction the same post-test instrument was re-administered after reshuffling as cognitive retention test after 2 weeks of post-test to determine the cognitive retention of the students. The hypotheses were tested at 0.05 level of significance using two-way Multivariate Analysis of Covariance (MANCOVA). MANCOVA is an extension of ANCOVA it is used when there is more than one dependent variable which are cognitive achievement and cognitive retention in this study. These dependent variables should be related in some way, or there should be some conceptual reason for considering them together (Pallant, 2011). Pallant further said MANCOVA compares the groups and tells whether the mean differences between the groups on the combination of dependent variables are likely to have occurred by chance. To do this, MANCOVA creates a new summary dependent variable, which is a linear combination of each of the original dependent variables. It then performs an analysis of covariance using this new combined dependent variable. MANCOVA will tell if there is a significant difference between

the groups on this composite dependent variable; it also provides the univariate results for each of the dependent variables separately.

## 3. RESULT AND DISCUSSION

Two hypotheses were tested at 0.05 level of significance using two-way MANCOVA

**Hypothesis 1.** *There is no significant difference between BSIM group and lecture method group on students' cognitive achievement and cognitive retention in biology*

Table 3.Descriptive Statistics

| | GENDER | TEACHING METHODS | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| POST TEST SCORE | MALE | BSIM | 43.1364 | 9.27510 | 44 |
| | | LECTURE | 35.2759 | 6.70635 | 58 |
| | | Total | 38.6667 | 8.79281 | 102 |
| | FEMALE | BSIM | 41.7000 | 6.33627 | 30 |
| | | LECTURE | 30.5283 | 7.77472 | 53 |
| | | Total | 34.5663 | 9.03812 | 83 |
| | Total | BSIM | 42.5541 | 8.19312 | 74 |
| | | LECTURE | 33.0090 | 7.58647 | 111 |
| | | Total | 36.8270 | 9.11177 | 185 |
| RETENTION SCORE | MALE | BSIM | 45.6136 | 9.14538 | 44 |
| | | LECTURE | 37.2586 | 8.16617 | 58 |
| | | Total | 40.8627 | 9.51501 | 102 |
| | FEMALE | BSIM | 45.6333 | 7.21341 | 30 |
| | | LECTURE | 39.4528 | 8.93904 | 53 |
| | | Total | 41.6867 | 8.83166 | 83 |
| | Total | BSIM | 45.6216 | 8.36284 | 74 |
| | | LECTURE | 38.3063 | 8.57564 | 111 |
| | | Total | 41.2324 | 9.19919 | 185 |

There was a statistically significant difference between BSIM and lecture methods on the combined dependent variables as indicated in Table 4, F (2, 179) = 50.98, p = .000; Wilks' Lambda = .637; partial eta squared = .363. When the results for the dependent variables were considered separately, the BSIM and lecture methods have statistically significant difference at both post test and retention test levels, using a Bonferroni adjusted alpha level of .025. The post

test score was, F (1, 180) = 67.56, p = .000, partial eta squared = .273. While, the retention score was, F (1, 180) = 32.53, p = 0.000, partial eta squared = .153 as indicated in Table 5. An inspection of the mean scores indicated that BSIM reported higher level of post-test mean score as indicated in Table 3 (M = 42.55, SD = 8.19) than lecture (M = 33.01, SD = 7.59).At retention level BSIM has a mean score of (M = 45.62, SD = 8.36) which is high than lecture method with (M = 38.31, SD = 8.58).

Table 4. Multivariate Tests of Students Achievement and Retention in Biology

| Effect | | Value | F | Hypothesis df | Error df | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|---|
| Intercept | Pillai's Trace | .798 | 353.222[b] | 2.000 | 179.000 | .000 | .798 |
| | Wilks' Lambda | .202 | 353.222[b] | 2.000 | 179.000 | .000 | .798 |
| | Hotelling's Trace | 3.947 | 353.222[b] | 2.000 | 179.000 | .000 | .798 |
| | Roy's Largest Root | 3.947 | 353.222[b] | 2.000 | 179.000 | .000 | .798 |
| PRETEST | Pillai's Trace | .010 | .860[b] | 2.000 | 179.000 | .425 | .010 |
| | Wilks' Lambda | .990 | .860[b] | 2.000 | 179.000 | .425 | .010 |
| | Hotelling's Trace | .010 | .860[b] | 2.000 | 179.000 | .425 | .010 |
| | Roy's Largest Root | .010 | .860[b] | 2.000 | 179.000 | .425 | .010 |
| GENDER | Pillai's Trace | .039 | 3.616[b] | 2.000 | 179.000 | .029 | .039 |
| | Wilks' Lambda | .961 | 3.616[b] | 2.000 | 179.000 | .029 | .039 |
| | Hotelling's Trace | .040 | 3.616[b] | 2.000 | 179.000 | .029 | .039 |
| | Roy's Largest Root | .040 | 3.616[b] | 2.000 | 179.000 | .029 | .039 |
| TEACHMET | Pillai's Trace | .363 | 50.981[b] | 2.000 | 179.000 | .000 | .363 |
| | Wilks' Lambda | .637 | 50.981[b] | 2.000 | 179.000 | .000 | .363 |
| | Hotelling's Trace | .570 | 50.981[b] | 2.000 | 179.000 | .000 | .363 |
| | Roy's Largest Root | .570 | 50.981[b] | 2.000 | 179.000 | .000 | .363 |
| GENDER * TEACHMET | Pillai's Trace | .015 | 1.333[b] | 2.000 | 179.000 | .266 | .015 |
| | Wilks' Lambda | .985 | 1.333[b] | 2.000 | 179.000 | .266 | .015 |
| | Hotelling's Trace | .015 | 1.333[b] | 2.000 | 179.000 | .266 | .015 |
| | Roy's Largest Root | .015 | 1.333[b] | 2.000 | 179.000 | .266 | .015 |

a. Design: Intercept + PRETEST + GENDER + TEACHMET + GENDER * TEACHMET

b. Exact statistic

Table 5 Tests of Between-Subjects Effects of Students Achievement and Retention in Biology

| Source | Dependent Variable | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|---|
| Corrected Model | POST TEST SCORE | 4733.833[a] | 4 | 1183.458 | 20.206 | .000 | .310 |
| | RETENTION SCORE | 2597.124[b] | 4 | 649.281 | 9.008 | .000 | .167 |
| Intercept | POST TEST SCORE | 19742.840 | 1 | 19742.840 | 337.080 | .000 | .652 |
| | RETENTION SCORE | 25611.389 | 1 | 25611.389 | 355.333 | .000 | .664 |
| PRETEST | POST TEST SCORE | 27.644 | 1 | 27.644 | .472 | .493 | .003 |
| | RETENTION SCORE | 87.770 | 1 | 87.770 | 1.218 | .271 | .007 |
| GENDER | POST TEST SCORE | 372.153 | 1 | 372.153 | 6.354 | .013 | .034 |
| | RETENTION SCORE | 75.211 | 1 | 75.211 | 1.043 | .308 | .006 |
| TEACHMET | POST TEST SCORE | 3956.998 | 1 | 3956.998 | 67.560 | .000 | .273 |
| | RETENTION SCORE | 2344.822 | 1 | 2344.822 | 32.532 | .000 | .153 |
| GENDER * TEACHMET | POST TEST SCORE | 116.578 | 1 | 116.578 | 1.990 | .160 | .011 |
| | RETENTION SCORE | 54.053 | 1 | 54.053 | .750 | .388 | .004 |
| Error | POST TEST SCORE | 10542.631 | 180 | 58.570 | | | |
| | RETENTION SCORE | 12973.881 | 180 | 72.077 | | | |
| Total | POST TEST SCORE | 266179.000 | 185 | | | | |
| | RETENTION SCORE | 330092.000 | 185 | | | | |
| Corrected Total | POST TEST SCORE | 15276.465 | 184 | | | | |
| | RETENTION SCORE | 15571.005 | 184 | | | | |

a. R Squared = .310 (Adjusted R Squared = .295). b. R Squared = .167 (Adjusted R Squared = .148

**Hypothesis 2.** *There is no significant difference between male and female students' cognitive achievement and cognitive retention in biology*

There was a statistically significant difference between male and female students on the combined dependent variables as indicated in Table 4, F (2, 179) = 3.62, p = .029; Wilks' Lambda = .961; partial eta squared = .390. When the results for the dependent variables were considered separately, the males and females have statistically significant difference at post testonly as indicated in Table 5, using a Bonferroni adjusted alpha level of .025.The post test score was, F (1, 180) = 6.35, p = .013, partial eta squared = .034. While, at retention level was, F

(1, 180) = 1.04, p = .308, partial eta squared = .006. An inspection of the mean scores indicated that males reported higher level ofposttest score as indicated in Table 3 (M = 38.67, SD = 8.79) than females (M = 34.57, SD = 9.04).At retention males have a mean score of (M = 40.86, SD = 9.52) slightly lower than female mean score of (M =41.69, SD = 8.83).

**3.2** *Findings*

1. BSIM group performed significantly better than lecture method group at combined dependent variables and separately at each dependent variable.
2. Males performed better than females at the combined dependent variables and at post-test level only.
3. Males and females performed significantly the same at retention level with females having slightly higher mean difference than males.

**3.3** *Discussion*

A Two-way Multivariate Analysis of Covariance was performed to investigate the effect of BSIM on students' cognitive achievement in biology. Two dependent variables were used: cognitive achievement test and cognitive retention test. The independent variables were teaching methods (BSIM and Lecture) and gender used as moderator variable. Preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance, covariance matrices, and multicollinearity, with no serious violations noted.

The results of this study indicated that, BSIM enhanced students cognitive achievement as well as retaining the leant materials, this is in line with the findings of Dhaaka (2012) who concluded that for learning of concepts in Biology of ninth class students (secondary school students) BSIM was more effective than conventional method of teaching. This means it has very important implications for day –to- day classroom teaching and also for the benefit of the students. It also makes the teaching process interactive, lively and interesting. Sushma (1987) investigated the effect of the BSIM, Concept Attainment Model and Traditional teaching on pupil's achievement as well as their attitude towards BSIM and CAM. Sushma found out that BSIM and CAM were more effective than traditional teaching. While, Tabbasum (1993) compared the effectiveness of BSIM with Advance Organizer Model of teaching on pupil's achievement in biology, pupil's interest in inquiry activities and pupil's reactions towards the

model. Findings indicated that Advance Organizer Model is more effective as compared to BSIM in terms of pupil's scholastic achievement. However, when pupil's interest in inquiry activities was taken into account BSIM has proved significantly more effective than the Advance Organizer Model. Pupils reacted more favorably towards the BSIM than the Advance Organizer Model. This finding revealed why males performed better than females when taught with BSIM. Sakiyo and Waziri (2015a) revealed that, males are more interested in making inquiry much more than their females counterpart, BSIM as an approach to scientific inquiry benefits male students more than females students, this is because inquiry requires active participation of students in which females consider themselves as inferior in anything that requires active participation. In retaining the learnt materials females performed better than males this may be as a result of more practice of learnt materials by females much more than males, while male students are busy making practical activities in the class.

**3.4** *Conclusion*

BSIM is a fast track method of teaching that is having a capacity to solve the long lasting problem of poor academic achievement of students in biology. This model is better for male students because of the inquiry nature it has.

**3.5** *Recommendation*

The study made the following recommendations:-

1. It is evident that, BSIM is effective in improving students' achievement in biology. Therefore, teachers should use this teaching model to facilitate their biology teaching.
2. State governments should organize symposium and workshops and make it compulsory for practicing teachers so that they can embrace the skills of the teaching model for effective implementation of the BSIM in teaching biology.
3. Pre-service teachers should be exposed to BSIM
4. BSIM should be suggested for some biology content areas in the curriculum especially very difficult concepts

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