Interaction Effect of Two Instructional Strategies and Mental Ability on Students' Achievement in Abstract Concepts in Biology

Gabriel Segun ADEWUMI
Department of Science Education,
Faculty of Education, Prince Abubakar Audu University,
Anyigba, Kogi State, Nigeria
adewumigabriel60@gmail.com; +2347064877444

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Gabriel Ademakinwa ADEOYE
Department of Biology,
Kwara State College of Education, Oro, Nigeria
gabrieladeoye@kwcoeoro.edu.ng; +2348062624181
ORCID: https://orcid.org/0000-0002-5004-2861

Abstract

This study determined the interaction effect of two instructional strategies (Project and Inquiry) and mental ability on students' achievement in abstract concepts in Biology. The pretest-posttest control group, quasi-experimental design was adopted for the study. 120 SSII Biology students from six co-educational schools in two Local Government Areas of Kwara State were randomly assigned to treatment groups. The instruments used were: The abstract Concepts in Biology Achievement Test (r=0.86), Biology Students Mental Ability Test (r=0.87), and Teachers' Instructional guides on Project and Inquiry strategies. The research questions were answered while the hypotheses were tested using Analysis of Covariance at 0.05 level of significance. The 2-ways interaction effect of treatment and mental ability on students' achievement in abstract concepts in biology was significant F(2, 107) = 3.006, P > 0.05, partial η2 =0.053). The low mental ability students exposed to project strategy had the highest post-achievement means score ($\bar{x}$ =24.28), followed by low mental ability students exposed to inquiry strategy ($\bar{x}$ =21.42), high mental ability students in the project strategy ($\bar{x}$ =20.22), high mental ability students in the inquiry strategy ($\bar{x}$ =17.15), and high mental ability students exposed to conventional strategy ($\bar{x}$ =17.29), while low mental ability students exposed to conventional strategy ($\bar{x}$ =16.88) had the lowest posttest achievement in abstract concepts in Biology. Thus, the interaction is disordinal. Based on the findings, project and inquiry strategies should be adopted for the improvement of student's mental ability and achievement in abstract concepts in biology.

Keywords: Project and Inquiry Instructional strategies, Achievement in biology, Mental ability, Abstract concepts.

Introduction

Biology is the science concerned with the study of diverse living organisms including plants, animals, and micro-organisms. The place of biology cannot be overemphasized in the lives of all human being in that biology attempts to uncover the unifying principles that exist among diverse organisms having morphological and functional inequalities. As a field of study, the scope of Biology covers the study of both living and non-living things together with their interactions with one another. The importance of Biology is evident in all fields of education such as agriculture, medicine, and pharmacy. Adeoye, Bello, and Abimbola (2022) posited that biology is a very important science subject that is a basic requirement for further learning of several science-related professional courses like nursing, agriculture, pharmacy, medicine, and so on. Biology helps in the production of high-yielding varieties of crop plants that are disease resistant.

Chukwuemeka (2011) and Ezekiel, Yilshik, and Joseph (2021) stressed that a comprehensive knowledge of the theoretical and practical aspects of biology is requisite for the provision of the three basic necessities of life and living a favorable life in the environment. Thus, the Biology curriculum at the senior secondary school level is designed to equip learners with the knowledge of key concepts in biology, the environment and the world at large, as well as develop necessary communication, critical and problem-solving skills in learners so as to prepare the students for workplace and future self-sustainability (Federal Ministry of Education, FME, 2014).

Despite the robust nature and objectives of teaching and learning Biology as highlighted in the curriculum, students still find some biological concepts such as enzyme, Mendelian genetics, hormones, and chromosome difficult to comprehend (Cimer, 2012). Available statistics from the West African Examinations Council (WAEC) Chief Examiner's Reports (2010, 2011, 2012, 2013, 2014, 2017 & 2018) also affirmed the spite of poor performances of students in some biology concepts. For instance, WAEC Chief Examiner's reports (2012 &2013) showed that many examinees could not define genotype,

gene mutation, and so on. Also, the WAEC Chief Examiner's reports (2010, 2017 & 2018) revealed that candidates were unable to list transmittable characteristics, draw genetics crosses properly, and those candidates who attempted the genetic diagram perform it wrongly.

Students' poor performance in Biology has been attributed to a mirage of factors one of which is the use of inappropriate pedagogy by most Biology teachers (Adeoye, 2022; Awolere, 2015; Ogundiwin, 2013). Hence researchers such as Babayemi (2014), Ibitoye (2021), and Ogundiwin (2013) suggested the use of active learning strategies. Among the strategies that have been explored in previous researches are; Experiential strategy by Awolere (2015), Inquiry strategy by Laksama (2017), Critical exploration strategy by Oloyede (2014), Adewumi (2014), puzzled based critical thinking motivation strategies by Ogundiwin (2013). Despite all these strategies, students still experienced a high rate of poor performance in the senior secondary school certificate examinations.

One of the active instructional strategies that caught the attention of researchers is the Project and inquiry Strategies. Project instructional strategy is a systematic strategy that facilitate learning through an extended inquiry processes that is organized around complex, and carefully structured products and tasks (Anette & Maija, 2022; Olatoye & Adekoya, 2010). The project strategy of teaching involves assigning a particular work to students to complete during their leisure and reporting back to the teachers as at when due. There are two types of project methods they are group and individual project methods. This research work is focused on group project strategy and individual project strategy.

Project strategy is an intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning an investigation, researching conjectures, and searching for information and coherent arguments (Aksela & Haatainen, 2019; Anette & Maija, 2022). Project strategy has been identified by Anette and Maija (2022) as consisting components that can adequately motivate teachers and students to work cooperatively whilst guiding students to perceive and understand all the necessary steps required to arrive at a logical conclusion.

Inquiry strategy on the other hand is a student and teacher-centered instructional strategy that engages students in real world questions which is chosen within a broad thematic framework. In inquiry style or strategy learners tries to discover and reason out

answers to problems through step-wise approaches involving rigorous and diligent search with minimum guidance from the teacher. Inquiry is often widely used in other terms such as inquiry-based teaching and inquiry-based strategy without clarifying connections and distinctions (Katja, Malcolm & Anna-Maria, 2017). Inquiry strategy involves investigation, searching, defining a problem, formulating hypothesis, gathering and interpreting data, and arriving at logical conclusions. The teacher needs to shift to learner-centered strategies of teaching by giving assignments and classactivities' that will challenge the learner's imagination.

In the course of focusing on the student's performance, mental ability, and gender usually suffice and oftentimes, students' mental ability might affect their achievement in biology. Ibitoye (2021) reported that mental ability has been established to impact the achievement of learners in biology. Adewumi, (2014) described mental ability as the level of cognitive achievement demonstrated when pupils are exposed to education processes that make them progress from a state of ignorance to a level where knowledge, talents, and skills are acquired and utilized. The students with high mental ability were able to understand their studies very well, grasp vital information and perform excellently in the examination compared with low mental ability students. Akinbobola, (2015) observed that the educational system in Nigeria is made up of students with various mental ability levels. Therefore, any improvement in instructional strategy will impact and affect learners' mental ability level. When mental ability is high or strong learning is fast and easy, conversely when mental ability is low or weak, learning becomes a struggle and difficult.

Gender has also remained an important variable which is significant to education since it has been linked with students' achievement. Gender refers to the classification of human being on the basis of sex due to the roles they perform. Previous studies show that on the average the performance of girls outweighed that of boys (Adewumi, 2014). The study of Yuniskurin, Noviyanti, Mukti, Mahana, and Zubidah (2019) also show that female has better spelling ability and thus do well in writing, literacy, and tests of general knowledge in education. In contrast, Ekon and Eni (2015), and Okafor (2021), showed that women were not only weakly represented, their levels of achievement in the fields of sciences and technology where low compared to the males.

Many studies have explored the effectiveness of different teaching and learning strategies for enhancing learners understanding of genetics. For instance, scientific inquiry method was investigated by Abd-Hamid, Campbell, Der, Packenham, and Wolf (2012), cooperative and inquiry-based methods were researched by Nkok (2019), and the genetics exordium method by Yan (2019). However, not much has been done using two strategies of teaching and mental ability together in the area of abstract concepts in Biology. It is this gap that this research work stands to fill. This research work seeks to find out the interaction effect of two instructional (Project and Inquiry) strategies and mental ability together with gender on students' achievement in abstract concepts in Biology.

Purpose of the Study

The main purpose of this study was to investigate the interaction effect of two instructional (Project and Inquiry) strategies and mental ability on students' achievement in abstract concepts in Biology in Kwara State. In specific terms, the study sought to;

1. Determine the difference between the achievements mean score of the students exposed to project and inquiry strategies in abstract concepts in biology and compare with their counterpart taught using conventional strategy.
2. Examine the interaction effect of treatment (project and inquiry) and mental ability on student achievement in abstract concepts in biology.
3. Find out the interaction effect of treatment (project and inquiry) and gender on student achievement in abstract concepts in biology.

Research Questions

Three research questions were formulated to guide the study:

1. What is the difference between the achievements mean score of the students exposed to project and inquiry strategies in abstract concepts in biology and compare with their counterpart taught using conventional strategy?
2. Is there any significant mental ability difference in the achievement mean scores of students expose to project and inquiry strategies in abstract concepts in biology and their counterpart taught using the conventional strategy?
3. Is there any significant gender difference in the achievement mean scores of students expose to project and inquiry strategies in abstract concepts in biologyand their counterpart taught using the conventional strategy?

Research Hypotheses

To guide the study three null hypotheses were formulated and were tested at 0.05 level of significance:

H_{01}: There is no significant difference in the achievements mean score of students exposed to project and inquiry strategies in abstract concepts in biology and their counterpart taught using the conventional strategy.

H_{02}: There is no significant interaction effect of treatment (project and inquiry) and mental ability on student achievement in abstract concepts in biology and their counterpart taught using the conventional strategy.

H_{03}: There is no significant interaction effect of treatment (project and inquiry) and gender on student achievement in abstract concepts in biology and their counterpart taught using the conventional strategy.

Methodology

This study adopted the pretest-posttest control group quasi-experimental research design. The population consisted of all senior school students in Oke-ero and Irepodun Local Government Areas while the target population comprised senior school students in SSS II offering Biology. A sample of 120 students was randomly selected using balloting. Two instruments were used for data collection which are Abstract Concepts in Biology Achievement Test, the achievement test consists of two sections, A and B. Section A seeks personal information on the students while section B consists of the achievement test made up of 30 items. Originally, 60 questions were set on abstract concepts. The questions were given to four teachers teaching biology in secondary school and one experience evaluator to establish the validity of the questions. This was carried out in order to ascertain whether the instrument is fit for the students. After their scrutiny, 50 questions were left. These 50 questions were the one that falls within the discriminating power of 4-7 as those that fall below 4 was considered too simple and those that fall above 7 were considered to be difficult for the students. Trial-testing of the instrument was done in a school not selected for the main study. Kr-20 was used in analyzing the data and 0.86 was obtained as the reliability coefficient.

Biology Students Mental Ability Test (BSMAT). The face and content validation of Biology Students Mental Ability Test was determined by subjecting it to the scrutiny.

The test was than administered to SSII students in the concerned schools using the split-half method of odd and even numbers of the items. The reliability coefficient was calculated and using Kuder Richardson (Kr-21), 0.87 was obtained as reliability. In addition, the draft of the Teacher's Guide on (project, inquiry, and conventional) strategies and evaluation sheet was given to five experienced Biology tutors in selected secondary schools. This was done in order to ensure the face, content and construct validity of the guide and evaluation sheet. These teachers are seasoned WAEC, NECO, and NABTEB examiners, and based on their comment and suggestion necessary amendments were made.

The researchers administered the instruments as pre-test and the student's scores were recorded. Thereafter, the researchers taught the experimental groups 1 and 2 the abstract concepts using project and inquiry strategies, while control group was taught with conventional method. The abstract concepts that were selected for the purpose of this study were related to evolution and molecular Biology and genetics. The treatment lasted for six weeks. The data collected were analyzed using descriptive statistics, Analysis of Covariance and Scheffe Posthoc test at 0.05 level of significance.

Results

Research Question 1: What is the difference between the achievements mean score of the students exposed to project and inquiry strategies in abstract concepts in biology and compare with their counterpart taught using conventional strategy?

Table 1: Descriptive Statistics of Achievement Associates with Treatment

Parameter	**Achievement Scores**		
	Project Strategy	**Inquiry Strategy**	**Conventional Strategy**
No of cases	34	46	40
Pre-test mean	13.09	9.63	9.98
Pre-test SD	3.11	2.67	3.08
Post-test mean	23.21	17.80	17.20
Post-test SD	3.01	5.01	5.81
Mean Gain	+9.12	+8.17	+7.22

Table 1 shows that the mean gain score for project strategy was 9.12 while that of inquiry strategy was 8.17 over that of conventional strategy which was 7.22. The highest mean gain was amassed by students exposed to project strategy as compared to their counterparts exposed to inquiry strategy. However, students exposed to inquiry strategy did better than those exposed to conventional strategy.

Research Question 2: Is there any significant mental ability difference in the achievement mean scores of students expose to project and inquiry strategies in abstract concepts in biology and their counterpart taught using the conventional strategy?

Table 2: Descriptive Statistics of Achievement Associates with Mental Ability

Parameter	**Achievement Scores**	
	Low mental ability	**High mental ability**
No of cases	41	79
Pre-test mean	12.30	9.91
Pre-test SD	3.13	3.06
Post-test mean	22.17	17.56
Post-test SD	4.04	5.44
Mean Gain	+9.87	+7.65

Table 2 indicates the descriptive statistics of students' achievement scores (high and low mental abilities). The mean gain scores for low mental ability students (9.87) is higher than that of high mental ability students (7.65). This implies that the two instructional strategies enhanced students' mental prowess and ability.

Research Question 3: Is there any significant gender difference in the achievement mean scores of students expose to project and inquiry strategies in abstract concepts in biologyand their counterpart taught using the conventional strategy?

Table 3: Descriptive Statistics of Achievement Associates with Gender

Parameter	Achievement Scores	
	Male	Female
No of cases	50	70
Pre-test mean	11.20	10.39
Pre-test SD	3.52	3.07
Post-test mean	21.94	17.13
Post-test SD	4.13	5.42
Mean Gain	+10.74	+6.74

Descriptive statistics of students' achievement in Table 3 indicates greater improvements for male students (10.74) over the female students (6.74).

H_{01}: There is no significant difference between the achievements mean score of students exposed to project and inquiry strategies in abstract concepts in biology and their counterpart taught using the conventional strategy.

Table 4: ANCOVA of post-test achievement scores of students by treatment, mental ability and Gender

Source	Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Corrected Model	1749.922	12	145.827	87.27	.000	.495
PREACH	31.183	1	31.183	1.866	.175	.017
Main Effect: Treatment Group	403.061	2	201.530	12.061	.000*	.184
Mental Ability	75.354	1	75.354	4.510	.036*	.040
Gender	26.390	1	26.390	1.579	.212	.015
2-ways Interactions Treatment x Mental Ability	100.449	2	50.225	3.006	.050*	.053
Treatment x Gender	49.557	2	24.778	1.483	.232	.027
Mental Ability x Gender	60.473	1	60.473	3.635	.059	.033
3-way Interaction Treatment x Mental Ability x Gender	192.386	2	96.193	5.757	.004*	.097
Error	1787.945	107	16.710			
Total	47468.000	120				
Corrected Total	3537.867	119				

*Significant at p<0.05

Table 4 shows that there was a significant main effect on treatment on the Academic Achievement of the Students ($F_{2,\ 107}$) = 12.061 P <.05, η^2 = 0.184). The effect size of 18.49% was fair. Therefore, the null hypothesis is rejected. Thus, the achievement of students exposed to treatment was significant.

Table 5: Scheffe Post-hoc Tests Analysis of Post-tests Achievement Score According to Treatment Group.

Treatment	N	Mean	Project strategy	Inquiry strategy	Conventional strategy
Project strategy	34	23.21		*	*
Inquiry strategy	46	17.81	*		*
Conventional strategy	40	17.26	*	*	

Furthermore, the significant difference obtained in Table 4 was traced using Scheffe post-hoc test as presented in Table 5. Table 5 revealed that group 1 (project strategy) was significantly different from Inquiry and conventional strategies in their achievement scores. Inquiry strategy was significantly, different from project and conventional strategies in achievement scores. These reveals that the direction of increasing effect of instructional strategy (treatment) on abstract concept achievement was conventional strategy not performing better than Inquiry strategy, Inquiry strategy not performing better than project strategy.

H_{02}: There is no significant interaction effect of treatment (project and inquiry) and mental ability on student achievement in abstract concepts in biology and their counterpart taught using the conventional strategy.

Figure 1: Graph showing the interaction between post-test of treatment and mental ability

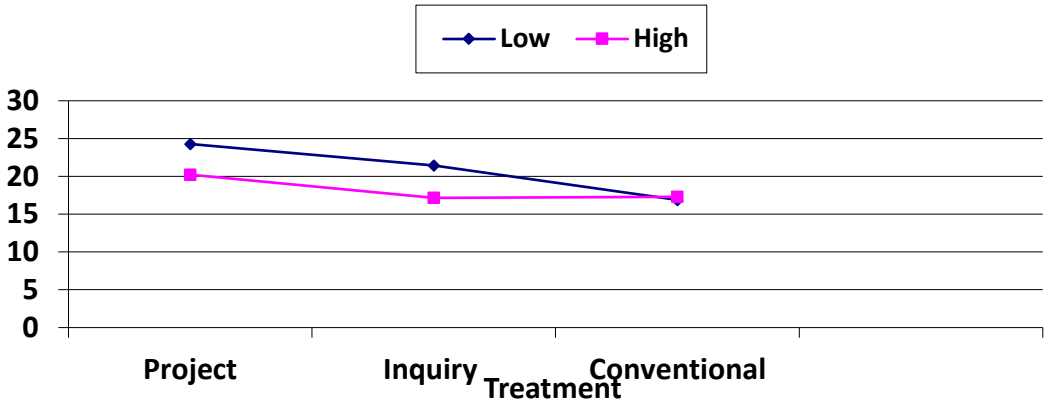

Figure 1 showed the interaction between mental ability and treatment. The interaction was disordinal both treatment and mental ability had a joint effect on achievement. The highest contribution came from project strategy low mental ability

students (M = 24.28) while the least effect is from conventional strategy low mental ability (M = 16.89).

H_{03}: There is no significant interaction effect of treatment (project and inquiry) and gender on student achievement in abstract concepts in biology and their counterpart taught using the conventional strategy.

Table 4 indicated that the interaction between treatment and gender was not significant F $(_{2, 107})$ =1.483, $P > 0.05$; partial eta squared (η^2) = 0.027. The effect size of 2.7% was fair, on the basis of this finding, hypothesis 3 not rejected.

Discussion of findings

The study determined the interaction effect of two instructional (project and inquiry) strategies and mental ability on student's achievement in abstract concepts in biology. The result indicated that the mean score of post-tests of the experimental group was higher than that of the mean score of the post-test of the control group. Also, the low mental ability students from experimental group had higher mean gain than the high mental ability students, and the male respondents from the experimental group had a higher mean score than their female counterpart.

Further findings revealed that the interaction between treatment and mental ability was significant. This finding shows that project and inquiry instructional strategies enhanced students' achievement over and the conventional strategy. This result suggests that the project and inquiry strategies effectively facilitated the achievement of learners than the conventional strategies. These may be attribute to the systematic and organized nature of the project and inquiry strategies in which learners where allowed to engage in various learning activities that enabled them to find out and develop their own knowledge of the abstract concepts individually or in groups and use their thinking skills for planning, execution, evaluation, reporting and recording. The students also formulated hypothesis, gather materials, record and analysis data and draw conclusion on the lessons all by themselves with minimal teacher interference. This result agrees with Olatoye and Adekoya (2010) who worked on three teaching strategies project, demonstration and lectures strategies. It was found that students exposed to project strategies had the most significant improvement in their achievement scores. It is also in consonance with the

finding of Aktamis, et al (2016), that inquiry strategy contributed significantly to a better understanding of abstract biology concepts than the conventional strategy.

The significant interaction between treatment and mental ability implies that the treatment is suitable for both low and high-mental-ability students concerning the abstract concepts in biology. Project strategy low mental ability students had the highest contribution while the least contribution came from conventional strategy low mental ability students. Although the project strategy low mental ability group had higher posttests mean scores than higher mental ability counterpart but the difference was not significant. This research result corroborates the finding of Adeyemi and Awolere, (2016), Adewumi (2014) and Nnorom, (2013) that high mental ability students perform better in Biology than low mental ability students. It however, disagrees with the finding of Ogundiwin, (2013) and Ibitoye, (2021) who reported that mental ability does not an influence student achievement in biology

Conclusion

The present study shows that project and inquiry strategies are effective at improving student's mental ability and academic achievement in abstract Biology concepts than conventional strategy. The reason for this was that the two instructional strategies enhanced the development of mental ability (critical thinking) of students' because it allowed them to actively participate in learning activities and create positive environment for effective interaction. It is noteworthy that students showed a higher level of commitment and involvement to solving abstract concepts and related problems in Biology when taught using these strategies.

Recommendations

From the results obtained and the discussion made, the following recommendations are therefore made:

1. Project and inquiry instructional strategies should be adopted as effective and viable strategies for studying abstract concepts in Biology.
2. Biology teachers should embrace activity-based learning which gives learners the chance to actively participate in the process of knowledge construction.

3. In-service teachers should vary and use instructional strategies that are in consonance with students' mental ability rather than stick with only one method of instruction.

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