Restructuring teaching and learning of biology for academic excellence in a conventional classroom using integrated innovative formative assessment techniques

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Abstract: The study examined the effect of integrated Innovative Formative Assessment techniques (IIFAT) on students' academic achievement in biology. Two research questions and three null hypotheses, tested at 0.05 alpha levels, guided the study. A non-randomized control group design was adopted. 48 (17 males and 31 females) SS1 students obtained using multi-stage sampling procedure from the 5572 secondary school year one (SS1) biology students in Awka Education Zone, Anambra State, comprised the sample size. A Biology Achievement Test (BAT), developed using a well-constructed test blue print, with a reliability coefficient of 0.85 established using Kuder-Richardson 20 (KR-20) was used for data collection. Mean and standard deviation were employed to answer the research questions, and Analysis of covariance (ANCOVA) to test the null hypotheses at 0.05 level of significance. The findings of the study revealed that integrating innovative formative assessment techniques in the conventional lecture method significantly improved secondary school students' academic achievement in biology more than the Demonstration method. On gender, the study revealed that although female students achieved higher than their male counterparts, the difference is not statistically significant. Based on the findings, the study recommended among other things that biology teachers should be trained on the integration of innovative formative assessment techniques into the conventional classroom during the teaching of biology for improved academic achievement.

Keywords: biology, academic excellence, integrated innovative formative assessment strategy, gender

Introduction

Teaching and learning for academic excellence, in a biology classroom, has ushered in the era of innovations in the teaching process, evidently shown by the

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numerous research works done on various innovative instructional approaches that may be employed in the classroom to enhance academic achievement of students in biology in secondary schools. Despite the educational implications of these innovative approaches as well as its assumed implementations in the classroom, it is sad to note that students' performance in biology in external examinations, such as West African Secondary School Certificate Examinations (WASSCE), still has not reached the expectancy of education stakeholders as evidently shown in the West African Examinations Council (WAEC) statistics reports for biology from 2017-2021. That is, for 2017, for aggregate of A_1-C_6, a percentage pass of 55.57 was recorded, 55.10% in 2018, 55.63% in 2019, 63.23% in 2020 and 58.09% in 2021.

In the quest to ascertain what challenges mar the implementations of these innovative instructional approaches in schools, Okoli (2023), in her study, identified lack of professional development, ignorance, poor applications and utilization of effective formative assessments, poor financial resources for technology driven learning and lack of ICT knowledge as major challenges affecting the effective implementations of the innovative instructional approaches in the biology classrooms. Supporting the premise, Nwuba et al. (2023b) reported that due to the intricacies associated with implementing these innovative approaches in the classroom coupled with low incentives and motivation from the education board, most secondary school teachers' in Nigeria resort back to their conventional methods of instruction with the aim to cover the syllabus within the limited allocated time, using the available knowledge and resources.

Conventional methods of instruction according to Nwuba et al. (2022) refer to approaches to teaching that involves the teacher in front of the learner's disseminating information and the learners taking down the information. They are teacher-centred methods frequently utilized in the classroom that involves less participation on the part of students (Ufommadu & Okoli, 2019). These methods, which include the lecture, discussion, team teaching and demonstration method, although widely recognized and utilized by teachers, as asserted by Paris (2014), because of their wide range of advantages that include faster coverage of content within a shorter time, usefulness in teaching a large population with limited resources as well as the development of students' listening, language, and secretarial skills, have been criticized by many because of their shortcomings in achieving a lesson stated objectives, inculcating in students' problem solving, critical thinking and decision making skills as well as fostering meaningful learning. Considering these shortcomings, the study advocated for the integration of innovative formative assessment techniques into these conventional methods during classroom instruction to foster and promote meaningful learning, for improved academic performance.

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Formative assessment also called "assessment for learning" according to Okoye et al. (2019) refers to tools that identify misconceptions, struggles, and learning gaps along the way, and assess how to close these gaps while learning is in progress. In its innovative form, they are those newly employed classroom assessment tools used to ascertain learners' assimilation level of a taught concept while developing and fostering their ability levels and problem-solving skills in the process (Umar & Ameen, 2021). Similarly, Nwuba et al. (2023a) defined them as those novel and creative tools employed by teachers in the classroom to not only efficiently improve classroom delivery but also develop higher mental process skills in learners. Hence, innovative formative assessment techniques are simply those resources employed by teachers during the teaching and learning process to ascertain a learner's strength (s) or weakness (es) for improved classroom delivery.

Innovative formative assessment techniques (IFAT) are vast and wild. Sewagegn (2019) highllighted peer assessment, debates, observation, group work, Laboratory works, student self-assessment, Quizzes, project or seminar works and presentations, portfolios, the use of technology in the assessment process, or the assessment of multiple drafts of written work or projects as the major forms of alternative formative assessment. Similarly, Raja and Shirley (2022) listed Assistments, Edpuzzle, Edulastic, Explain everything, Flipgrid, Gimkit, Google classroom question tool, Formative, Google forms, InsertLearning, Jamboard, Kahoot, Nearpod, Padlet, Plickers, Quizizz as web-based formative assessment tools. In their study, Nwuba et al. (2023a) identified brainstorming, think-pair share, one minute summary/essay, use of analogy, use of concept maps, performance tests, use of demonstration stations, exit cards, graphic organizers, peer and self-assessments, students generated questions, inside-outside circle, individual whiteboards, three minute pause, problem solving, E-resources, reciprocal teaching, metacognition, idea spinner, take and pass, authentic assessments, list 10 things and numbered heads together as the different types of IFAT science teachers are aware of. For the purpose of this study, the researchers' selected think-pair-share, student generated questions, numbered heads together and use of concepts maps. The researchers' purposely selected these four because they require little professional development for easy usage, no financial resources for utilization and ICT applications which have been clearly identified, abi initio, as factors that limit the implementation of innovative instructional strategies in the classroom.

Think-Pair-Share (TPS) is an assessment technique that combines thinking with communication. It is an active learning technique that allows students to reason through a challenge, collaborate with a colleague in a group, and discuss solutions in the classroom (Falebita et al., 2022). In integrating TPS in the classroom, teacher presents the class with a task after a brief discussion of the task. At the thinking stage, the teacher allows the students to think about the task and pen down personal ideas about the task

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presented to them, this last for 3 to 5mins. At the pairing stage, the teacher allows the students to form groups of twos and maximum of three, within which they compare the individual responses and agree on the best solution. At the sharing stage, representative from the groups are allowed to share their conclusions with the entire class. After this, the teacher summarizes and concludes the task (Falebita & Olofin, 2020). The second technique adopted was Student generated question (SGQ). SGQ also referred to as student generated instructional materials is an assessment technique that asks learners to provide objects that other students can use in their own learning. Integrating SGQ in a conventional classroom, according to Coppola and Pontrello (2019) involves five stages: reading a given material, generating questions from it by the students, gathering and distributing the questions by the teacher, solving the questions by students, and finally reviewing the questions and answers by the teacher and students.

Another technique adopted was Numbered heads together (NHT). NHT is a cooperative instructional approach in which members of a team work on a task together with each member ensuring he/she knows the answer(s) to the task or learned material, since the group is not informed in advance who the representative of the group will be (Nwuba et al., 2023b). Integrating NHT in the classroom according to Ellena and Suminar (2018) is done in five-phases: Numbering: The teacher divides the students into small groups of 4 or 5 members with each given a number. Phase 2. Asking/Posing a question or presenting a problem: the teacher may ask a question, give a learning material or presents a problem to the class and give the groups time to think and work together. Phase 3. “Heads Together”: the students put their heads together, discuss and members agree on a common answer Phase 4. Answering the Question: numbers are called at random and only members with the number answer 5. Feedback: the teacher asks if there are other students who want to refute or add an answer and finally, provides feedback to the answer. The fourth and final assessment technique adopted was Concept maps. Concept maps, according to Iroko and Alaoye (2021), are diagrammatic representations that display meaningful relationships between concepts as propositions connected together by terms, circles, and cross links. They are a unique way of representing information involving three stages: presentation of a list of concepts under the discussed topic by the teacher, using line to represent the relational ties between these concepts, and labeling these linking relationships (Chawla and Singh (2015).

When effectively integrated and implemented, Cambridge Assessment International Education (2017) posited that IFAT are very useful during the teaching and learning process, for effective classroom delivery, as they help teachers and students evaluate progress in terms of understanding and skills acquisition, as well as provide guidance and feedback for subsequent teaching and learning. Summarizing the above, PowerSchool (2023), in their publication, asserted that the benefits of

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innovative formative assessment, when effectively integrated, include defined learning goals, increased rigor, improved academic achievement, enhanced student motivation, increased student engagement, focused and targeted feedback, personalized learning experiences, self-regulated learning, and Data-driven decisions. Considering these benefits associated with adopting IFAT in the teaching and learning process, the researchers' advocated for its integration into the conventional lecture method to ascertain its effect on students' academic achievement in biology.

Biology, a science subject taught at the senior secondary school level in Nigeria, occupies a unique position in the school curriculum. Nwuba et al. (2023c) defined it is a branch of natural sciences that focuses on living organisms, their life styles and relationships with each other. As a subject, which deals on living organisms and the environment, its importance to man cannot be overemphasized. This is probably why, Owolabi et al. (2019) asserted that biology not only serves as a prerequisite subject for the ideal preparation and pursuing of a number of careers in sciences, such as medicine, pharmacy, biochemistry, botany, nursing, and zoology, but also equips an individual with useful knowledge needed in solving everyday life challenges ranging from pollution, diseases, pests, food scarcity, conservation of resources as well as for scientific and technological advancements. Considering these benefits, it becomes imperative that biology be taught using approaches that can help students not only excel in the subject in all forms of examinations but also acquire the necessary skills and knowledge needed, from the subject, for effective reforms in the society.

Academic excellence, also termed academic achievement, is the end product of any academic setting. Nwuba et al (2023c) defined it as the product of one's time, hard work and devotion after being exposed to a learning program, usually measured in grades. Academic achievement in every organized academic programme is considered central and paramount, as it informs the managers the extent to which the set objectives have been achieved. In light of this, and for sustainable development of individuals, it becomes imperative that appropriate approaches be employed to foster meaningful learning, for improved academic excellence, irrespective of gender.

Gender is a social construct assigned to boys and girls. Obikezie et al. (2023) defined it as a universally accepted attribute assigned to individuals based on their sexual differences. In the present day, issues related to gender and its influence on academic achievement of students in sciences have drawn a lot of attention from science educators based on the number of studies done to this effect. While some researchers' (Osalusi & Ajibefun, 2018; Orheruata & Oyakhirome, 2019) reported that that formative assessment techniques favoured boys in social studies and basic science respectively, some in mathematics (Moyosore, 2015; Wafubwa & Csikos, 2022; Agwagah & Ezeike, 2023) reported the contrary. However, on further testing, the same cited researchers reported that although the differences exist, they are not statistically

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significant, irrespective of subjects. These inconclusive findings call for further studies, especially in biology, to ascertain if IIFAT is gender friendly or biased. Taking cognizance of this, the study therefore explored the effect of IIFAT on secondary school students' academic achievement in biology, with gender as the intervening variable.

To achieve the purpose of the study, the following research questions guided the study:

1. What is the difference in the mean achievement scores of secondary school students' taught biology using integrated innovative formative assessment technique (IIFAT) and those taught using Demonstration method (DM)?

2. What is the difference in the mean achievement scores of secondary school students' taught biology using IIFAT with respect to gender?

Hypothesis

The following null hypotheses were tested at 0.05 alpha levels.

1. No significant difference exists between the mean achievement scores of secondary school students' taught biology using IIFAT and those taught using DM.

2. There is no significant difference in the mean achievement scores of secondary school students' taught biology using IIFAT with respect to gender.

3. There is no interaction effect of gender and teaching methods on secondary school students' academic achievement in biology.

METHODS

Research Design

The research is a quasi-experimental research adopting a non-randomized control group design.

Research Participants

5572 (2,483 males and 3,089 females) SS1 students offering biology in the 62government owned secondary schools in Awka Education Zone, Anambra State, Nigeria, made up the population of the study. Using a multi-stage sampling procedure, a sample size of 48 SS1 biology students (17 boys and 31 girls) in the two intact classes sampled from two coeducational secondary schools were selected.

Instrument for Data collection

A 40-item biology achievement test (BAT) with four response options A-D, developed by the researchers' from WASSCE past questions, on the topics taught during the period of the study, using a well-planned test blueprint to ensure content coverage, was used for data collection.

Reliability of Instrument

The reliability of the instrument was that of internal consistency established using Kuder-Richardson 20 (KR-20) formula. This was done by administering the BAT to

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an intact class of 25 SS1 students, in a school in Aguata Education Zone, who were not enrolled in the study. The reliability coefficient for BAT was found to be 0.85.

Experimental Procedure

The study commenced with the briefing of the research assistants (biology teachers) from the two sampled schools, separately on three contacts. During the briefing, the biology teacher in the control group was asked to teach using the researchers' lesson plans on DM while the research assistant for the experimental group received a briefing about IIFAT, its types, and how to effectively integrate the selected IIFAT into the conventional lecture method, using the lesson plans developed by the researchers'. Following the briefing, the BAT was administered to the two drawn intact classes that were divided into the experimental (9 boys and 17 girls) and control (8 boys and 14 girls) groups as the pretest. Following the pre-testing, the two groups began a 4-week long treatment (teaching) activity. Both groups took a posttest after the treatment, which served as the post test score. Scores from both the administered tests were analyzed.

Data Analyses

Data collected were analyzed using mean and standard deviation to answer the research questions, and Analysis of covariance (ANCOVA) to test the null hypotheses at 0.05 level of significance. In taking decisions, null hypotheses is rejected if the Probability (P) value is less than or equal to the level of significance (0.05), if otherwise, the null hypotheses is not rejected.

RESULTS AND DISCUSSION

Results were presented in tables based on the research questions and hypotheses.

Research Question one: What is the difference in the mean achievement scores of students' taught biology using integrated innovative formative assessment technique (IIFAT) and those taught using Demonstration method (DM)?

Table 1

Achievement scores of students with respect to approaches (IIFAT and CLM)

		Pretest		Posttest		
Groups	N	Mean	SD	Mean	SD	Gain in Mean
IIFAT	26	17.85	1.03	26.69	1.21	8.84
DM	22	17.18	0.96	18.45	1.20	1.27
Mean Difference		0.67		8.24		7.57

Data in Table 1, reveals that students in the experimental group had mean achievement scores of 17.85 and 26.69 in their pretest and posttest respectively while their counterparts in the control group, who were taught with DM, had mean achievement scores of 17.18 for their pretest and 18.45 for their posttest. Students in the experimental group performed better than those in the control group, according to the mean difference of the gains in mean for IIFAT and DM, which was 7.57. In comparison to DM, the results showed that incorporating innovative formative

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assessment techniques when teaching biology greatly boosted students' academic progress.

Research Question 2: What is the difference in the mean achievement scores of secondary school students' taught biology using IIFAT with respect to gender?

Table 2

Achievement scores of students taught with IIFAT with respect to gender

		Pretest		Posttest		
Groups	N	Mean	SD	Mean	SD	Gain in Mean
MALE	9	17.11	1.98	25.56	2.50	8.45
FEMALE	17	18.24	1.21	27.29	1.55	9.05
Mean Difference		1,13		1.73		0.60

Analyzed data in table two reveals that the experimental group's male students had their pretest and posttest mean achievement scores to be 17.11 and 25.56 respectively, while the females' had mean achievement scores of 18.24 in their pretest and 27.29 in their posttest.. With 0. 60 mean difference in gain in mean, it can be inferred that when both students are taught selected topics in biology using integrated innovative formative assessment technique, the female students outperformed their male counterparts.

Null hypothesis one: No significant difference exists between the mean achievement scores of secondary school students' taught biology using integrated innovative formative assessment technique (IIFAT) and those taught using Demonstration method (DM).

Table 3

ANCOVA test of achievement scores with respect to approaches (IIFAT and CLM)

Dependent Variable: PRETEST

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Decision
Corrected Model	464.863[a]	4	116.216	7.652	.000	
Intercept	115.069	1	115.069	7.577	.009	
POSTTEST	438.127	1	438.127	28.848	.000	
METHOD	97.062	1	97.062	6.391	.015	Significant
GENDER	.011	1	.011	.001	.978	
METHOD * GENDER	.799	1	.799	.053	.820	Not Significant
Error	653.053	43	15.187			
Total	15888.000	48				
Corrected Total	1117.917	47				

a. R Squared = .416 (Adjusted R Squared = .361)

Two way ANCOVA test from table 3 reveals that at F value of 6.391, the P value is 0.015. Since the P value is less than 0.05 level of significance, the null hypothesis is rejected. This indicates that there is a significant difference between the mean achievement scores of students taught biology with IIFAT (experimental group) and that of those taught with DM (control group) in favour of those in the experimental group. This reveals that incorporating formative assessment techniques into the conventional lecture method during the teaching of biology provides an activity-based

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learning environment where students work together, exchange ideas as they guide their own learning under the guidance of the teacher.

Null hypothesis two: There is no significant difference in the mean achievement scores of secondary school students' taught biology using IIFAT with respect to gender.

Table 4

ANCOVA test of achievement scores using IIFAT with respect to gender

Dependent Variable: PRETEST

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Decision
Corrected Model	194.738[a]	2	97.369	4.546	.022	
Intercept	67.931	1	67.931	3.171	.088	
POSTTEST	187.301	1	187.301	8.744	.007	
GENDER	.961	1	.961	.045	.834	Not Significant
Error	492.647	23	21.419			
Total	8968.000	26				
Corrected Total	687.385	25				

a. R Squared = .283 (Adjusted R Squared = .221)

ANCOVA test from table 4 shows that at F-value of 0.045, the P-value is 0.834. The null hypothesis is not rejected because the P-value at df 1 and 23 is greater than 0.05 level of significance. This demonstrates that there is no significant distinction between male and female students who were taught biology using IIFAT in terms of their mean achievement scores. This indicates that IIFAT is not gender biased,

Null hypothesis three: There is no interaction effect of gender and teaching methods on secondary school students' academic achievement in biology.

ANCOVA test from table 3 shows that at F-value 0.053, P-value is 0.820. The null hypothesis is not refuted because the P-value at df 1 and 43 is greater than 0.05 alpha levels. Revealing that the academic success of students in biology was unaffected by the combination of gender and teaching strategies.

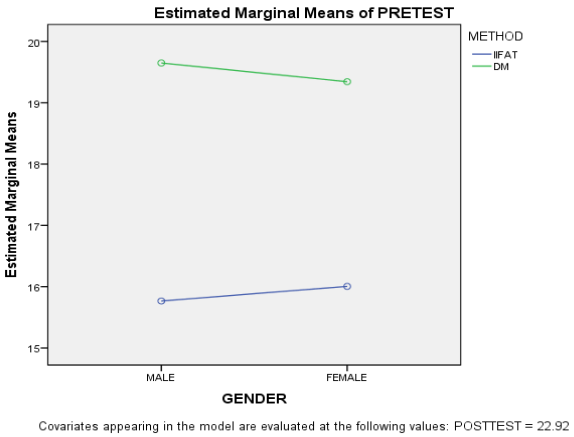

Figure 1: Profile Plot of Interaction Effect of Gender and Teaching methods on Academic Achievement of Students in Biology.

The finding of the study revealed that students taught biology with integrated innovative formative assessment techniques (IIFAT) gained in achievement more than those, in the control group, taught using Demonstration Method (DM). This difference

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in achievement was proved significant by the test of hypothesis 1 examined in table 3 of the study. This improved achievement may be attributed to the uniqueness of each of the formative assessment technique (think-pair-share, student generated questions, numbered-heads together and use of concept maps), integrated into the conventional lecture method, which provided a learner based environment where students were actively involved in interacting with each other and teachers constantly assessing students to re-teach concepts students find difficult to learn in Biology. Consequently, students tended to learn more and achieve at a higher level when they responded to assessment results by knowing where they were on the path to success, where they were headed, and what they needed to do to reach that accomplishments. These findings agree with the reports of Moyosore (2015), Osalusi and Ajibefun, (2018) Orheruata and Oyakhirome (2019), Galle and Kukwi (2020), Wafubwa and Csikos (2022), and Agwagah and Ezeike (2023) who reported in their respective studies, in basic science, social studies, economics and mathematics, that IIFAT is more effective in enhancing student's achievement than the conventional methods of instruction. The findings however disagrees with that of Ashdale (2020) who reported, in his study, that no significant difference exists in the mean achievement scores of students taught biology with progress tracker formative assessment technique and those taught with the conventional method.

The finding, on influence of gender, indicated that there was no significant gender difference in the effect of IIFAT on the academic achievement of secondary school year one students in biology. In order words, the treatment had similar effect for both male and female students exposed to the technique. This implies that differences in performance between male and female students is not significant even though the result from the research showed relative difference in the mean scores of the male and female students, in favour of the females. The finding of this study lends credence to the findings of Moyosore (2015), Olagunju (2015), Osalusi and Ajibefun, (2018) Orheruata and Oyakhirome (2019), Wafubwa and Csikos (2022), and Agwagah and Ezeike (2023) who reported in their respective studies that although there was a relative difference in the mean achievement scores of male and female students exposed to IIFAT, the difference was not statistically significant. On interaction effect of teaching methods and gender on achievement of students in biology, the finding of the study revealed that there was no interaction effect of teaching methods and gender on students‟ achievement in biology. The finding concur with that of Wafubwa and Csikos (2022).

CONCLUSION

Based on the findings, the study concluded that integrating formative assessment techniques into the conventional methods of teaching promotes students' academic achievement in biology, and hence, should be a go-to for conventional teachers, since

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IIFAT provides a gender friendly learning environment similar to most innovative instructional approaches. As in using IIFAT, both teachers and students are actively involved in the learning process, with the teacher monitoring, identifying students learning problems and adjusting teaching to meet their needs as the students' interact with each other, exchange ideas while fostering meaningful learning.

Based on the conclusion, the following recommendations were made:

1. Biology teachers should be trained by education stakeholders, through workshops and conferences, on how to effectively integrate the innovative formative assessment techniques in the teaching of biology in a conventional classroom, for improved performance.

2. Teachers during the integration of these innovative formative assessment techniques, should encourage student-student interaction as this will enable students interact, exchange information and make notable contributions as they learn from each other things they cannot learn from the teacher or textbooks.

The major limitations of the study are outlined as follows:

1. The study was delimited to two intact classes of small size, this as a result may limit the generalizability of the study.

2. The study was carried out using only one level of students (SS1 biology students)

3. The study was conducted using only two topics (Plant and Animal nutrition) and limited to only four forms of innovative formative assessments

In light of these limitations, the following suggestions for further studies were made:

1. A larger sample size should be sampled and studied to improve the generalizability of the study.

2. This study may be conducted using other levels of secondary school students to ascertain if the same effectiveness of IIFAT will be established.

3. Other forms of formative assessments should be adopted and studied to ascertain their effectiveness using other topics in biology.

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