



EFFECT OF DESIGN-BASED THINKING INSTRUCTIONAL APPROACH ON SECONDARY SCHOOL STUDENTS' ACADEMIC ACHIEVEMENT IN BIOLOGY IN AWKA EDUCATION ZONE

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ABSTRACT

This study investigated the effect of the Design-Based Thinking Instructional Approach (DBTIA) on secondary school students' academic achievement in Biology in Awka Education Zone of Anambra State, Nigeria. Two research questions guided the study and three null hypotheses were tested at 0.05 level of significance. The quasi-experimental research design, specifically the pretest-posttest non-randomized control group design, was adopted. The population comprised 3,891 Senior Secondary Two (SS2) Biology students in the 62 public secondary schools in the zone. A multi-stage sampling procedure was used to draw a sample of 122 students (60 males and 62 females) from two co-educational schools, one assigned to the experimental group taught with DBTIA and the other to the control group taught with the Conventional Lecture Method (CLM). Data were collected using the Biology Achievement Test (BAT), a 50-item multiple-choice instrument developed by the researchers and validated by experts in Science Education and Measurement and Evaluation. The reliability of the BAT, established using the Kuder-Richardson Formula 20 (KR-20), yielded a coefficient of 0.88. Data were analysed using mean and standard deviation to answer the research questions, while Analysis of Covariance (ANCOVA) was used to test the hypotheses. Findings revealed that students taught Biology using DBTIA had a significantly higher mean gain achievement score (14.33) than those taught using CLM (6.00), $F(1, 117) = 75.482, p < 0.05$. There was no significant difference between the achievement scores of male and female students taught with DBTIA, $F(1, 117) = 0.201, p > 0.05$, and no significant interaction effect between instructional strategy and gender on students' academic achievement, $F(1, 117) = 0.272, p > 0.05$. The study concluded that DBTIA is a more effective and gender-inclusive instructional approach than the Conventional Lecture Method for improving students' academic achievement in Biology. It was recommended, among others, that Biology teachers should adopt DBTIA in place of CLM, particularly for topics requiring deep conceptual understanding.

Keywords: Design-Based Thinking, Instructional Approach, Academic Achievement, Biology, Gender



Introduction

Science occupies a central position in national development, providing the knowledge, skills and innovations required to address societal challenges and promote sustainable economic growth (UNESCO, 2021). Among the various branches of science, Biology occupies a prominent position in the Nigerian secondary school curriculum owing to its focus on living organisms and its application to healthcare, agriculture, environmental conservation and biotechnology. Campbell and Reece (2020) defined Biology as the scientific study of life and living organisms, encompassing their structure, growth, evolution, distribution and ecological relationships. As noted by Ezeudu and Obi (2022), the subject integrates theoretical knowledge with practical experience, enabling students to understand life processes and apply biological concepts to real-world situations.

Academic achievement refers to the extent to which a learner has successfully attained the intended learning outcomes or educational objectives, as measured through tests, examinations and other standardized evaluation procedures. According to Nwankwo and Nancy (2026), academic achievement refers to the extent to which students have mastered the knowledge, skills and competencies taught, thereby meeting the educational objectives prescribed by a curriculum. In Biology education, academic achievement serves as an important indicator of the effectiveness of teaching and learning, reflecting students' understanding of biological concepts, practical competencies and scientific reasoning. Despite the importance of Biology in science and national development, students' academic achievement in the subject in Nigeria has remained inconsistent over the years. Analysis of West African Senior School Certificate Examination (WASSCE) results indicates fluctuations in the percentage of candidates obtaining credit passes (A1–C6) in Biology, with credit pass rates ranging from approximately 54.7% to 76.4% between 2017 and 2023. Successive WASSCE Chief Examiners' Reports have consistently identified weaknesses in candidates' practical skills, interpretation of biological diagrams, scientific reasoning and application of biological concepts to real-life situations, underscoring the need for innovative learner-centred instructional approaches capable of improving academic achievement in Biology. Several factors have been associated with the fluctuating academic achievement of students in Biology, including inadequate laboratory facilities, insufficient instructional materials and large class sizes (Umeh and Eze, 2020), as well as teacher-related factors such as the continued reliance on traditional teaching methods (Adebayo and Yusuf, 2019). One major reason for inconsistent learning outcomes is the heavy reliance on the Conventional Lecture Method (CLM), a teacher-centred approach in which the teacher serves as the primary source of knowledge while students listen, take notes and receive instruction with limited active participation (Nworgu, 2019). Although convenient for covering extensive content within limited time, the lecture method positions students as passive recipients of information rather than active constructors of knowledge, thereby limiting active participation and problem-solving ability (Abdulrahman and Ibrahim, 2021; Afolabi and Akinbobola, 2020).

Consequently, educational researchers have increasingly advocated the adoption of innovative instructional methods capable of enhancing students' academic achievement in science. Ogbu and Igboanugo (2022) assert that innovation in science pedagogy is essential to helping students



connect abstract concepts to real-world contexts. One such promising innovative strategy is the Design-Based Thinking Instructional Approach (DBTIA), a human-centred, problem-solving instructional method that engages students in iterative cycles of designing, testing, evaluating and refining solutions to real-world problems. According to Pusca and Northwood (2018), design-based thinking is a creative approach involving empathizing with users, defining problems, ideating solutions, prototyping and testing. Originally developed in engineering and product design fields, it has been widely adapted for classroom use to promote creativity, collaboration and systematic problem-solving.

Design-based thinking instructional approach follows an iterative process comprised of five stages: empathy, definition, ideation, prototype and testing (Cabana, Camacho and Noguera, 2019). In the empathy stage, students focus on understanding the needs and challenges to be solved. The definition stage entails the clear articulation of the learning problem, while in the ideation stage students generate possible solutions (Hoa, 2025). During prototyping, students build a prototype of their chosen solution, and in the final testing stage they evaluate the prototype, learning from failure while developing critical thinking and problem-solving skills (Kelley, 2017). In Biology, where students must connect theoretical knowledge to practical application, this iterative learning cycle is particularly valuable, with teachers acting as facilitators who guide students through structured thinking processes that integrate scientific reasoning with creative exploration.

Studies have demonstrated the effectiveness of design thinking in improving students' academic achievement, particularly in STEM fields. Trinidad (2024) reported that learners' academic achievement was significantly improved by the application of the design-thinking strategy, while Udeani and Okekwo (2023) found that the design-based thinking instructional strategy improved students' academic achievement in Biology among senior secondary school students in Lagos State. Similarly, Yu (2024), in a meta-analysis of empirical studies, reported that design-thinking instructional approaches had a significant positive effect on students' learning performance compared with traditional teaching approaches. These documented benefits suggest that design thinking may offer a viable solution to the persistent achievement challenges observed in secondary school Biology instruction.

Although the Design-Based Thinking Instructional Approach has been recognized for its potential to enhance academic achievement in Biology, its effectiveness may not be uniform across all learners. Gender is an important factor to consider when evaluating instructional effectiveness, and research findings on gender differences in science achievement remain mixed. Okeke and Nduka (2020) reported no significant gender differences in Biology achievement, whereas other studies indicate that gender gaps may emerge depending on the learning environment or teaching method (Ezinne and Uzoechi, 2021). In the context of Anambra State, Ofor and Nwosu (2022) found that some innovative approaches reduced gender gaps, whereas traditional methods tended to produce inconsistent outcomes across male and female learners, reinforcing the need to examine how design thinking may affect learners differently based on gender.



Despite extensive national discussion on improving science instruction and emerging international evidence supporting design thinking, there remains a noticeable gap in localized research assessing its effect on Biology achievement in Awka Education Zone. Existing studies in the zone have focused on correlates of achievement such as motivation, self-regulation and cognitive skills, but few have experimentally tested the effectiveness of structured, innovative instructional strategies like design thinking. It is against this backdrop that this study sought to determine the effect of the Design-Based Thinking Instructional Approach on secondary school students' academic achievement in Biology in Awka Education Zone, and to establish whether gender moderates this effect. Specifically, the study sought to determine the:

1. Mean achievement scores of students taught Biology using Design-Based Thinking Instructional Approach (DBTIA) and that of those taught using Conventional Lecture Method (CLM).
2. Mean achievement scores of male and female students taught Biology using DBTIA.
3. Interaction effect of instructional strategies and gender on students' academic achievement scores in Biology.

Research Questions

The following research questions guided the study:

1. What are the mean achievement scores of students taught Biology using DBTIA and that of those taught with CLM?
2. What are the mean achievement scores of male and female students taught Biology using DBTIA?

Hypotheses

The following null hypotheses were tested at 0.05 level of significance:

1. There is no significant difference in the achievement scores of students taught Biology using DBTIA and that of those taught with CLM.
2. There is no significant difference in the achievement scores of male and female students taught Biology with DBTIA.
3. There is no significant interaction effect of instructional approaches and gender on students' academic achievement in Biology.

Methodology

The study adopted the quasi-experimental research design, specifically the pretest-posttest non-randomized control group design, since random assignment of participants to experimental and control groups was not feasible without disrupting the timetable of the sampled schools. The study was carried out in Awka Education Zone, one of the six education zones in Anambra State, comprising 62 government-owned secondary schools spread across Awka South, Awka North, Anaocha, Dunukofia and Njikoka Local Government Areas. The population of the study comprised 3,891 Senior Secondary Two (SS2) students offering Biology across the zone. A sample of 122 SS2 Biology students (60 males and 62 females) was drawn from two co-educational public secondary schools using a multi-stage sampling procedure. Simple random sampling was first used to select two Local Government Areas (Anaocha and Awka South); purposive sampling was then



used to select co-educational schools with qualified Biology teachers and functional laboratories; one school was randomly assigned to the experimental group and the other to the control group by a toss of a coin; and one intact SS2 class was selected from each school by the lucky-dip method. Data were collected using the Biology Achievement Test (BAT), a 50-item multiple-choice instrument developed by the researchers, adapted from past WASSCE Biology questions and structured according to a table of specification covering the cognitive domains of Bloom's Taxonomy. Each correct response attracted two marks while an incorrect or omitted response attracted zero. The instrument was validated by three experts from the Faculty of Education, Nnamdi Azikiwe University, Awka, comprising two specialists in Science Education and one in Measurement and Evaluation. The reliability of the BAT was established using the Kuder-Richardson Formula 20 (KR-20), appropriate for dichotomously scored objective tests, and yielded a coefficient of 0.88, indicating that the instrument was sufficiently reliable for the study.

The experimental procedure lasted six weeks. In the first week, research assistants (Biology teachers) were briefed and given lesson plans, with the experimental group teacher trained in DBTIA and the control group teacher trained in CLM; a pretest was then administered to both groups using the BAT. The treatment phase, lasting four weeks, involved the experimental group being taught selected topics in the Human Respiratory System and Ecology using DBTIA, while the control group was taught the same content using CLM. In the sixth week, following a period of revision, a reshuffled version of the BAT was administered as a posttest to both groups. Extraneous variables such as teacher differences, the Hawthorne effect, non-randomization and pretest sensitization were controlled through standardized lesson plans, the use of regular intact classes, wide geographical separation of the schools, and the application of Analysis of Covariance (ANCOVA). Data collected were analysed using mean and standard deviation to answer the research questions, and Analysis of Covariance (ANCOVA) to test the hypotheses at the 0.05 level of significance, with the aid of SPSS version 27.

Result Presentation

Research Question 1: What are the mean achievement scores of students taught Biology using DBTIA and that of those taught with CLM?

Table 1: Mean and Standard Deviation on Achievement Scores of Students Taught Biology Using DBTIA and Those Taught with CLM

Method	N	Pretest Mean	SD	Posttest Mean	SD	Mean Gain
DBTIA	70	23.80	7.39	38.13	6.38	14.33
CLM	52	23.85	6.32	29.85	6.42	6.00
Mean Diff.		-0.05		8.28		8.33

The result in Table 1 shows that students taught Biology using DBTIA had a pretest mean achievement score of 23.80 and a posttest mean achievement score of 38.13, with a mean gain of 14.33, while those taught using CLM had a pretest mean of 23.85 and a posttest mean of 29.85, with a mean gain of 6.00. The difference between the mean gain achievement scores of the two



groups is 8.33 in favour of DBTIA, suggesting that DBTIA is more effective than the Conventional Lecture Method in improving students' academic achievement in Biology.

Hypothesis One: There is no significant difference in the achievement scores of students taught Biology using DBTIA and that of those taught with CLM.

Table 2: Summary of Analysis of Covariance (ANCOVA) of Achievement Scores of Students Taught Biology with DBTIA and Gender

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3891.649	4	972.912	37.058	.000
Intercept	4001.276	1	4001.276	152.409	.000
Pretest Scores	1822.923	1	1822.923	69.435	.000
Instructional Strategies	1981.680	1	1981.680	75.482	.000
Gender	5.268	1	5.268	.201	.655
Instructional Strategies * Gender	7.145	1	7.145	.272	.603
Error	3071.671	117	26.254		
Total	153003.000	122			
Corrected Total	6963.320	121			

Table 2 shows that there is a significant effect of instructional strategy on students' achievement in Biology, $F(1, 117) = 75.482$, $p = .000 < .05$. Since the p-value is less than 0.05, the null hypothesis is rejected, indicating a significant difference between the mean achievement scores of students taught Biology using DBTIA and those taught using CLM, in favour of DBTIA. This result suggests that students exposed to DBTIA achieved significantly higher academic achievement in Biology than those taught using the Conventional Lecture Method.

Research Question 2: What are the mean achievement scores of male and female students taught Biology using DBTIA?

Table 3: Mean and Standard Deviation on Achievement Scores of Male and Female Students Taught Biology Using DBTIA

Gender	N	Pretest Mean	SD	Posttest Mean	SD	Mean Gain
Male	30	23.50	7.53	38.00	6.49	14.50
Female	40	24.03	7.36	38.23	6.38	14.20
Mean Diff.		-0.53		-0.23		0.30

Table 3 reveals that male students taught Biology using DBTIA had a pretest mean achievement score of 23.50 and a posttest mean of 38.00, with a mean gain of 14.50, while female students had a pretest mean of 24.03 and a posttest mean of 38.23, with a mean gain of 14.20. The mean



difference in gain scores is 0.30 in favour of the male students, though the posttest scores of both groups are fairly comparable, suggesting that DBTIA is largely gender-neutral in its effect on students' academic achievement in Biology.

Hypothesis Two: There is no significant difference in the achievement scores of male and female students taught Biology with DBTIA.

As shown in Table 2, there is no significant effect of gender on students' achievement in Biology, $F(1, 117) = 0.201$, $p = .655 > .05$. Since the p-value is greater than 0.05, the null hypothesis is not rejected, indicating no significant difference between the mean achievement scores of male and female students taught Biology using DBTIA. This implies that the effectiveness of DBTIA in improving students' academic achievement in Biology was similar for both male and female students.

Hypothesis Three: There is no significant interaction effect of instructional approaches and gender on students' academic achievement in Biology.

Table 2 further shows that there is no significant interaction effect of instructional approach and gender on students' academic achievement in Biology, $F(1, 117) = 0.272$, $p = .603 > .05$. Since the p-value is greater than 0.05, the null hypothesis is not rejected, indicating no significant interaction effect between instructional approach and gender on students' academic achievement. This implies that the effect of DBTIA on students' academic achievement in Biology did not depend on gender; both male and female students benefited similarly from the instructional approach.

Discussion of Findings

The finding of this study showed that students taught Biology using DBTIA recorded a higher mean gain achievement score than those taught using CLM. This suggests that instructional approaches that engage learners in empathy, ideation, prototyping and testing of real-world problems promote deeper understanding and better academic performance in Biology than the conventional lecture method. The reason for this outcome may be that DBTIA requires students to actively construct knowledge through hands-on problem-solving activities rather than passively receiving information, thereby promoting meaningful learning, retention and improved academic performance. This finding corroborates that of Udeani and Okekwuo (2023), whose study revealed that the design-based thinking instructional strategy improved students' academic achievement in Biology among senior secondary school students in Lagos State. Similarly, this finding agrees with that of Trinidad (2024), who found that Biology students exposed to the design-thinking strategy performed significantly better academically than those taught using traditional instructional methods, and with Simeon, Samsudin and Yakob (2022), who reported that students exposed to the design-thinking instructional approach improved significantly in their academic achievement in Physics concepts.

The corresponding hypothesis revealed a significant difference between the achievement scores of students taught Biology using DBTIA and those taught using CLM, in favour of DBTIA. This indicates that DBTIA had a statistically significant positive effect on students' academic achievement in Biology, aligning with the findings of Udeani and Okekwuo (2023) and Trinidad



(2024), both of whom confirmed statistically significant improvements in the academic achievement of students exposed to design-thinking instructional strategies.

The finding also showed that male and female students taught Biology using DBTIA obtained fairly comparable posttest achievement scores and gains, with only a slight difference recorded in favour of the male students. This suggests that DBTIA is largely gender-neutral in its effect on academic achievement in Biology. The reason for this outcome may be that the collaborative, activity-based nature of DBTIA provides equal access to problem-solving experiences, prototyping activities and constructive feedback for students of both genders, thereby minimizing gender-based achievement disparities that are sometimes observed under conventional instructional approaches. This finding corroborates that of Simeon, Samsudin and Yakob (2022), whose study revealed no significant gender difference among students exposed to the design-thinking approach. However, it contrasts with that of Simeon, Samsudin and Yakaria (2020), who reported that male students recorded higher achievement scores than their female counterparts after being taught Physics using the design-thinking approach, an outcome that may be attributable to differences in subject area or prior exposure to STEM-related activities.

The corresponding hypothesis revealed no significant difference between the achievement scores of male and female students taught Biology using DBTIA, indicating that DBTIA affects the academic achievement of male and female students in a statistically similar manner. This aligns with the finding of Simeon, Samsudin and Yakob (2022), who statistically confirmed the absence of a significant gender difference among students exposed to the design-thinking approach, although it contrasts with Phothong, Chaimongkol and Ladachart (2023), whose study found that gender differences significantly influenced students' design-thinking mindset development, an outcome that may be due to differences in the variable measured, age group and instructional context.

Finally, the finding showed that there is no significant interaction effect of instructional approach and gender on students' academic achievement in Biology, suggesting that the combined effect of DBTIA and gender does not significantly influence students' academic achievement and that DBTIA is equally effective for both male and female students in improving achievement. The reason for this outcome may be that DBTIA's structured stages of empathy, ideation, prototyping and testing provide equitable learning opportunities that are not moderated by gender, resulting in similar achievement gains for male and female students. This finding corroborates that of Udo and Udofia (2021), whose study revealed no significant interaction effect between inquiry-based instructional strategy and gender on students' academic achievement in Chemistry, and that of Deslauriers, McCarty, Miller, Callaghan and Kestin (2019), who reported no significant interaction effect between instructional method and gender on students' academic achievement in Physics.

Conclusion

Based on the findings of the study, it was concluded that the Design-Based Thinking Instructional Approach (DBTIA) is more effective than the Conventional Lecture Method (CLM) in improving secondary school students' academic achievement in Biology within Awka Education Zone. The



approach appears to promote improved achievement outcomes irrespective of gender, as male and female students benefited comparably from its implementation, and the effectiveness of the instructional approach did not depend on gender, indicating that DBTIA is a gender-inclusive instructional strategy. Overall, the study highlights the instructional value of design-based thinking in fostering improved academic achievement in Biology at the secondary education level.

Recommendations

Based on the findings of the study, the following recommendations were made:

1. Biology teachers should adopt the Design-Based Thinking Instructional Approach (DBTIA) in place of the Conventional Lecture Method (CLM), particularly when teaching topics that require deep conceptual understanding, since the approach was found to significantly enhance students' academic achievement in Biology.
2. School principals and administrators should organise regular workshops, seminars and in-house training programmes to expose Biology teachers to the principles and stages of design-based thinking (empathy, ideation, prototyping and testing).
3. Curriculum planners and education policymakers should incorporate design-based thinking strategies into the Biology curriculum and instructional guidelines, providing clear frameworks and resources for teachers.
4. Teacher training institutions should embed design-thinking pedagogy into pre-service and in-service teacher education programmes, equipping Biology teachers with the skills needed to plan, implement and assess lessons using the approach.
5. Since DBTIA was found to be a gender-inclusive instructional approach, teachers and school administrators should implement it for mixed-gender classrooms without reservation, while future researchers should further investigate its effectiveness across other Biology topics, class levels and school contexts.

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