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Biology Reimagined: A test of Culturo-Techno-Contextual Approach (CTCA) in Boosting Students' Achievement

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A B S T R A C T

The prerequisite for learning science lies in students' ability to adapt to new stimuli in learning environments. This ability is often reflected in their readiness to apply newly acquired knowledge in different contexts. This study investigated a culturally-influenced pedagogy infused with technological and contextual features to improve biology learning. A total of 138 Senior Secondary II students participated, comprising 75 students (45 males, 30 females) in the CTCA group and 63 students (30 males, 33 females) in the lecture group, with an average age of 15 years. An explanatory sequential mixed-method design was used. Quantitative data were collected using the Plant Nutrition Achievement Test (PNAT), which had a reliability coefficient of 0.83, while qualitative data were obtained through the Biology Students Interview Protocol in Biology (SIPB). Descriptive statistics (mean, standard deviation, and thematic analysis) and ANCOVA at a 0.05 significance level were used for data analysis. The findings showed that CTCA students significantly outperformed the lecture group [$F(1,134) = 1655.16$, $p < .05$]. Students also expressed positive attitudes toward CTCA. The study concludes that CTCA enhances students' achievement in plant nutrition and recommends its adoption by biology teachers to engage students effectively.

1. Introduction

There is consensus among science educators that effective teaching is crucial for meaningful teaching and learning of science in secondary schools (Okunade 2024). Classroom science teaching is guided by the pedagogical knowledge of the teacher, and the ability to identify the appropriate approach, techniques and strategies for every concept intended to be taught. However, reports show that science teachers use inadequate instructional strategies. Numerous reasons for wanting people to have a strong grasp of science. For instance, maintaining the environment and its natural resources relies heavily on people's understanding of science and technology (Timiyan, 2022). Nonetheless, Timiyan noted that many individuals lack comprehension of science and its significant role in economic and social progress. They suggested that science and science education should be bolstered in developing nations through school instruction, enabling students to grasp the connection between science and society. However, despite scientific education being part of the curriculum in Nigeria, an example of a developing country, it still lags industrially and economically in development compared to developed nations (Investopedia, 2019).

Concerns about the inconsistency in the quality of science education at the senior secondary school level in Nigeria have been widely expressed. Ahmad and Halim (2024) identified several issues with teaching science, particularly biology, including inactivity, misrepresentation, passive learning, students' over-reliance on teachers and textbooks, poor performance, lack of skills and appropriate scientific attitudes, declining interest, and low enrolment in science courses. It is essential to teach science not just for knowledge acquisition but also for skill development. The primary factor contributing to these issues is the teaching methods used which are sometimes not appropriate (Ademola et al. 2023; Gbeleyi et al. 2023; Onowugbeda et al. 2023a). Researchers like Omotere (2013) and Omoifo (2012) have noted fluctuations in Nigeria's science education standard. Persistent poor performance in science subjects, particularly biology, at the School Certificate level like WAEC suggests that many secondary school biology teachers in Nigeria may not be using diverse teaching strategies to address the specific challenges of teaching and learning of biology (Ezugwu, Mbonu-Adigwe, Ibenegbu, & Okoye (2022).

The biology curriculum in Nigerian schools is designed to provide students with a comprehensive understanding of biological principles and processes. Beginning from the secondary level, students delve into foundational topics such as cell biology, plant nutrition, genetics, evolution, ecology, and human physiology. The objective of science education is to inspire student motivation and enhance access to science learning. Having being described as multifaceted, science education aims to enhance scientific literacy, promote critical thinking, and prepare students for various fields related to biology. The curriculum offers a comprehensive understanding of biological concepts while addressing the practical needs of society. Teachers play a crucial role in achieving this goal and improving students' understanding of science. Their beliefs about science, teaching methods, and students' learning influence their classroom decisions, acting as filters that shape their actions. Understanding these beliefs and how they guide instruction is essential for improving science education. There is a widespread movement aimed at reforming science education, which emphasizes a shift from traditional teacher-centered approaches to more student-centered methods. This shift requires teachers to acquire specific knowledge, including content knowledge and pedagogical content knowledge, allowing them to adapt reformed science curricula to meet the diverse needs and interests of their students (Brown & Livstrom, 2020).

Biology has one of the highest enrolments among the science subjects and plays a critical role in shaping students' understanding of the living world (especially its immediate environment) and its processes. Within the biology curriculum, plant nutrition is a fundamental topic that provides insights into essential biological processes such as photosynthesis, nutrient uptake, and growth. However, traditional lecture method often fail to engage students fully or facilitate deep understanding of biological concepts (Ibitoye 2021). Supporting this, Oyelekan, Igbokwe, and Olorundare (2017) confirmed that science teachers rarely use innovative teaching strategies in their biology lessons. This implies that while they may have strong knowledge of science content, they lack instructional expertise. Addressing this problem is crucial to equip students with the necessary skills to thrive in the modern age of science and technology and to fulfill the objectives of the Nigerian National Policy on Education (FRN, 2013), which aims to develop students' mental, physical, and social abilities to contribute meaningfully to students' achievement potentially leading to nation's advancement in science and technology.

Academic achievement refers to the extent to which students have gained knowledge and skills from a particular course of instruction. Akanni (2021), in his work said achievement is the scholastic standing of a student's performance at a given point in time. It also refers to cognitive scores or learning outcomes in a subject like biology. It encompasses cognitive scores or learning outcomes in subjects like biology and is centered on accomplishing predefined goals. The purpose of achievement testing is to help both teachers and students evaluate and assess the degree of success in mastering a given concept, whether before or after instruction. This process is also crucial for determining the effectiveness of the instruction itself.

Academic achievement is the outcome of an educational programme. It refers to an academic position a student occupies in the class relative to the position of others, in the same class, usually assessed by the teacher's use of rating scales, tests and examinations (Anekwe, 2011). Nwuba (2021) defined it as the gain in knowledge of a student which occurs as a result of taking part in a learning activity or programme. Hence, academic achievement maybe defined as a statistic report of a student's performance in an engaged educational (academic) programme. Most studies carried out in Nigeria have asserted that academic achievement of learners depend mostly on learners' proficiency in biology concepts. To attain the level of appreciating the objectives of biology education, there is need for students' centred approach to teaching.

The introduction to plant nutrition into the biology curriculum aims to address the basic and general topics on the importance of this area to meet nutritional requirements and promote crop growth, development (see Figure 1). This concept addresses important topics such as concepts of plant nutrition and its relationship with related disciplines; the concept of nutrient and criteria of essentiality; relative composition of nutrients in plants; nutrient accumulation by crops and crop formation; other chemical elements of interest in plant nutrition, such as potentially toxic and beneficial elements, with emphasis on silicon; and hydroponic cultivation, preparation, and use of nutritional solutions

Figure 1. Plant Nutrition

In Nigeria, one of the earliest approaches to teaching biology before independence is lecture, this method incorporates mere introduction of topic or concept (Tukur, Nurulwahida, Hi & Madya, 2019). Considering its limitations, Students are unable to develop their own knowledge during the lessons since they are not permitted to engage in the teaching-learning process. Previous studies presents the lecture approach as being less effective, yielding minimal results, the lecture technique has not benefited students much because of its passive nature, as it does not allow for active participation in learning (Obro, 2022). Teachers, trainers, and lecturers continue to use the lecture method as one of their most common means of transmitting knowledge and ideas. Lectures can be informative, dull, or overpowering, depending on the compelling nature of the topic, the presenter's approach, and the clarity of the material. The lecture technique typically involves one-way communication and little or no audience participation. The end consequence is audience misunderstanding, loss of information, and poor retention. This necessitates exploring innovative teaching frameworks that can enhance learning outcomes. One such promising approach is the Culturo-Techno-Contextual Approach (CTCA), which emphasises active student engagement, critical thinking, and real-world application of scientific knowledge.

CTCA and Science Learning

The Culturo-Techno Contextual Approach (CTCA) is a dividend of over 40 years of quest for a tool that can be used in breaking barriers to meaningful learning in science. Several methods of teaching science have been found to improve the learning of science concepts. These methods include cooperative learning, concept mapping, discovery learning, demonstration, argumentation, mastery learning and vee diagramming. Most, if not all the methods, singly or in combination have failed to sustainably promote meaningful learning of science to a level that can be regarded as significant in the face of contextual mitigating factors. The search for such a method which will foster meaningful learning and elevate the performance of students in school and public examinations led to the invention of the CTC Approach (Okebukola, 2020).

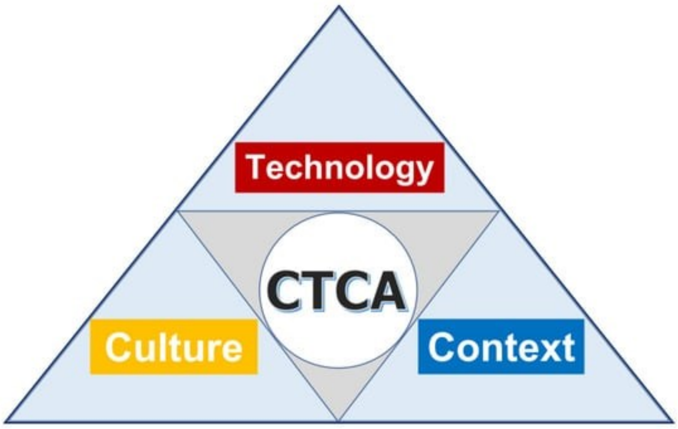

Figure 2. The three Elements of CTCA (Oladejo et al., 2023)

The approach is designed to overcome traditional obstacles to meaningful learning. These obstacles include fear of science due to its complex, imported language and mathematical emphasis; lack of adequate teaching and learning resources; the abstract nature of some concepts; and the perception that science is only for exceptionally gifted individuals. CTCA addresses these challenges by integrating three key frameworks: (a) the cultural context, which reflects the environment learners are familiar with; (b) technology mediation, which teachers and students increasingly rely on; and (c) the locational context (see Figure 2), which highlights the unique identity of each school and supports the use of relevant local examples and case studies in science lessons (Okebukola 2020). The CTCA framework, grounded in constructivist learning theories, posits that students construct their understanding and knowledge of the world through experiencing things and reflecting on those experiences. This theory contrasts sharply with traditional lecture-based teaching, which often places students in a passive role. By integrating CTCA into biology education, teachers can create more dynamic and interactive learning environments where students are encouraged to explore, question, and apply their knowledge in meaningful ways. (Onowugbeda et al., 2022)

The application of CTCA in biology education involves using a variety of steps (see Figure 3), including collaborative learning, problem-solving activities, and hands-on experiments. These methods align with the principles of constructivist theory, which advocates for learning as an active, contextualized process of constructing knowledge rather than acquiring it. By engaging students in activities that require them to think critically and solve problems, the CTCA framework helps to develop higher-order cognitive skills and a deeper understanding of the subject matter (Okebukola, 2020).

Furthermore, CTCA emphasizes the importance of the learning environment, suggesting that students learn best in environments where they can interact with peers and instructors, receive feedback, and reflect on their learning experiences. In the context of Lagos senior secondary schools, creating such environments may involve leveraging technology, utilizing available resources creatively, and fostering a culture of inquiry and collaboration among students. This holistic approach not only enhances academic performance but also prepares students for future educational and career opportunities Adam (2019). Given the dynamic nature of biological sciences and the rapid advancements in related fields, students must develop skills that go beyond rote memorization. The CTCA framework supports the development of these skills by encouraging students to explore real-world problems, conduct experiments, and engage in discussions that challenge their thinking (Okebukola, 2019). This approach is particularly relevant for the topic of plant nutrition, which has significant implications for agriculture, environmental sustainability, and food security.

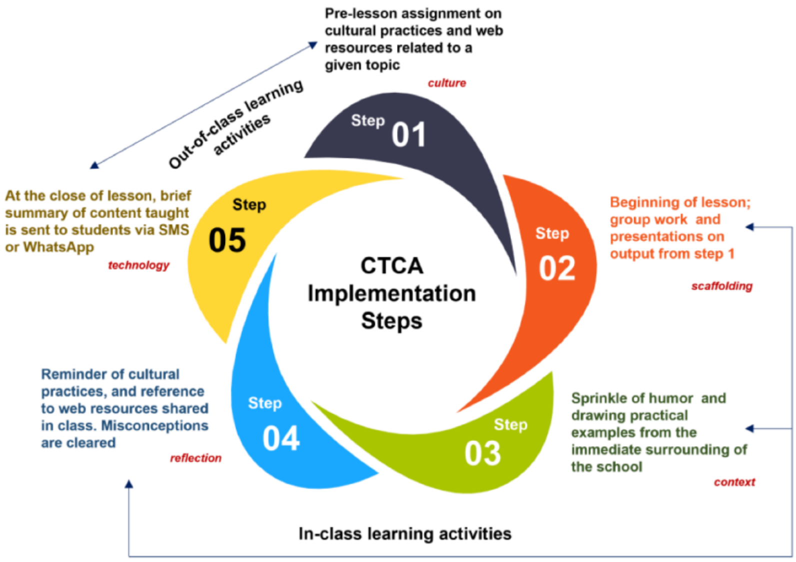

Figure 3. CTCA Implementation steps (Oladejo et al., 2023)

Ultimately, the goal of integrating the CTCA framework into biology education in Lagos senior secondary schools is to transform the teaching and learning process. By moving beyond traditional lectures and fostering a more interactive and student-centered approach, educators can better equip students with the knowledge, skills, and attitudes necessary to succeed in their academic pursuits and contribute meaningfully to society. The choice to focus on the CTCA framework for enhancing biology learning in Lagos senior secondary schools is justified by the urgent need to improve educational outcomes in this region. Traditional lecture-based teaching methods have shown limitations in effectively engaging students and facilitating a deep understanding of complex biological concepts. This is particularly evident in the topic of plant nutrition, where a thorough grasp of theoretical and practical aspects is crucial. By adopting the CTCA framework, educators can address these limitations and create a more effective learning environment that promotes active engagement and critical thinking (Onowugbeda et al., 2024).

There is a significant research gap in applying the CTCA framework in the context of secondary education in Lagos. While constructivist approaches have been widely studied and implemented in various educational settings globally, their specific impact on biology education in Lagos has not been thoroughly investigated (Ajayi et al., 2023; Leiber, 2022). This gap highlights the need for empirical studies exploring how CTCA can be tailored to Lagos schools' unique challenges and opportunities. In addressing this gap, the research can provide valuable insights into the effectiveness of CTCA in improving student learning outcomes and inform future educational practices and policies.

Moreover, the emphasis on plant nutrition as the focal topic is particularly relevant given its importance in the broader context of biology and its practical applications. Understanding plant nutrition is essential for addressing global challenges such as food security, sustainable agriculture, and environmental conservation. It is still a mirage that students could not answer questions appropriately on the concepts of plant nutrition (WAEC Chief Examiner's Report 2015-2019). Therefore, enhancing the teaching and learning of this topic through innovative frameworks like CTCA can have far-reaching implications. In improving students' comprehension and interest in plant nutrition, educators can contribute to developing a generation of informed and skilled individuals capable of tackling these critical issues. Based on the strength of this innovative approach, we conjectured that CTCA will enhance the achievement of biology students, particularly in plant nutrition.

Research questions

1. Is there any difference in the achievement of students taught plant nutrition using the Culturo-Techno Contextual Approach (CTCA) and the lecture method?

2. What are the views of biology students about the effectiveness of CTCA?

Research hypothesis

The study tested one null hypothesis at a 0.05 level of significance:

1. There is no statistically significant difference in the achievement of students taught plant nutrition using the Culturo-Techno Contextual Approach (CTCA) and the lecture method.

Theoretical Framework

Our study draws on Vygotsky's sociocultural theory, and Ausubel's theory of meaningful learning and advance organizers. Vygotsky's sociocultural theory emphasizes that child development is a socially mediated process, where children acquire cultural values, beliefs, and problem-solving skills through interactions with more experienced individuals. According to Vygotsky, engaging children in challenging, purposeful societal activities fosters their cognitive development. Interactions with others not only enhance the knowledge and skills a child gains but also contribute to the development of higher-order cognitive functions, such as formal reasoning. Central to his theory is the "Zone of Proximal Development" (ZPD), a developmental phase that arises through social engagement and determines the potential for cognitive growth (Vygotsky 1978). Full maturation of the ZPD requires active social participation. In our study, we consider social interaction and culture as key elements in learning in the CTCA, aiding cognitive development. Students engaged with More Knowledgeable Others (MKOs), such as parents, guardians, and online resources, to acquire subject-specific knowledge (Cultural Knowledge on Plant Nutrition).

Ausubel's theory of meaningful learning emphasizes the importance of connecting new knowledge to what learners already know. In biology, this means that students who can relate new information about topics like Plant Nutrition to concepts they are already familiar with will understand and retain the material better. When students approach a new lesson with background knowledge or experiences, they are more likely to grasp the content because they can link the new information to something they already understand (Ausubel 1963). This is crucial in subjects like biology, where complex processes and systems are often built upon prior knowledge. For example, if a student understands basic concepts of plant biology, such as photosynthesis, they can better understand how plants absorb nutrients and the role of minerals in their growth.

Advance organizers, as described in Ausubel's theory, play a key role in activating prior knowledge and preparing students to learn new material. In the context of biology, tasks such as reflecting on Indigenous knowledge related to plant nutrition or watching educational videos can act as advance organizers. These activities help students make connections between what they know and what they are about to learn. Reflecting on real-world examples, students activate their existing knowledge about plants and nutrition, which makes it easier for them to understand and relate to the new information being taught in class. In turn, this prepares them to grasp complex biological concepts more effectively.

For students learning about topics like Plant Nutrition, these pre-lesson tasks not only activate relevant prior knowledge but also provide them with a broader perspective that enhances their understanding. Exploring different viewpoints—such as cultural practices or digital resources—they enrich their cognitive frameworks and build a deeper understanding of the topic. As a result, students are more likely to achieve success in biology, as they are able to apply their prior knowledge and make connections between new concepts. This process of integrating new information with existing knowledge leads to meaningful learning, which can improve their comprehension, problem-solving skills, and overall achievement in the subject.

In collaboration, these theories explore the exploration of three components: culture, technology, and context for enhanced academic achievement in the teaching and learning of biology. Drawing on Vygotsky's sociocultural theory and Ausubel's theory of meaningful learning, the study examines how the CTCA leverages social interactions, cultural knowledge, and technology to create a dynamic learning environment. Adopting More Knowledgeable Others (MKOs) such as peers, teachers, and digital resources, the approach aims to engage students in the Zone of Proximal Development (ZPD), facilitating cognitive growth. Additionally, the CTCA incorporates advance organizers that activate prior knowledge, particularly cultural and technological resources, to foster deeper understanding and make biological concepts more relevant and accessible. The research investigates how this approach can bridge students' existing cultural frameworks with modern scientific content, ultimately boosting their achievement in biology.

2. Methodology

Design

This study employed an explanatory sequential mixed-method design, integrating quantitative and qualitative approaches to address the research problem comprehensively. The quantitative phase used a two-group pretest-posttest non-equivalent quasi-experimental design with two intact classes: an experimental group (CTCA) and a control group (lecture method). Intact classes preserved the natural classroom setting, minimized ethical constraints, and ensured feasibility. Both groups took a pretest using the Plant Nutrition Achievement Test (PNAT) to assess baseline knowledge. The experimental group underwent the CTCA intervention, while the control group received traditional lecture-based instruction. A posttest using the PNAT evaluated performance changes. The qualitative phase gathered data through the Students Interview Protocol in Biology (SIPB) to explore students' views and experiences with CTCA. These insights complemented the quantitative results, providing a nuanced understanding of CTCA's effectiveness in enhancing plant nutrition learning.

Context and Participants Details

The population of this study consisted of all the senior secondary school biology students in Lagos State. Lagos state is situated in the southwestern region of Nigeria and as at the time of this study, it consists of six education districts (Districts I - V). In Lagos state, junior and senior secondary schools are categorized into education districts based on geographical locations and for easy administration and quality control. Education District V was random has sixty-six senior secondary schools. All the districts share similar characteristics, in terms of teachers' qualifications, training support, and quality control under the same commission, which allowed for the selection of District V. Education District V, along with two public senior secondary schools in Lagos State, was randomly chosen using a simple ballot system. These schools were chosen from intact classes at two randomly selected schools located far apart one from the rural and the other from the urban area. This geographical isolation was designed to eliminate the chance of inter-group interaction, which could introduce biases or extraneous variables that could skew the results. The use of intact classes was required by school policies, which prohibited randomisation of students to avoid disruptions to regular academic activity. Furthermore, this strategy was logistically practical, saving time and resources that would have otherwise been spent on creating new randomised groups. It also decreased the possibility of disturbing the students' existing group dynamics and learning progress, in line with ethical considerations aimed at minimising any negative impact on education. By employing intact classes that represent typical classroom settings in Lagos State, the study ensured that its findings were relevant and suitable to the environment in which they were to be implemented.

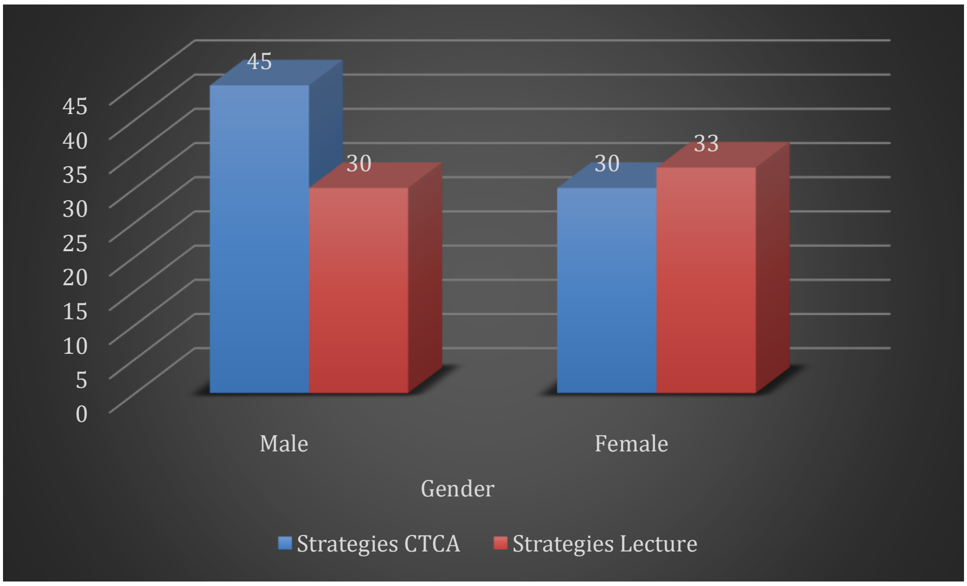

Figure 4. Shows the distribution of students (male and female) in the groups

A total of 138 senior secondary school two (SS 2) biology students in the two intact classes of the two selected schools participated in this study. One out of the two schools' intact classes was randomly assigned to CTCA group while the second group was assigned to the lecture method (control group). The total number of students in the CTCA group was 75 students (male 45, female 30), and the lecture group had 63 students (male = 30, female = 33). Also, the average age for the learners in each of the classes was 15 years.

Instrumentation

The data for this study were collected using two instruments: the Plant Nutrition Achievement Test (PNAT) and the Students Interview Protocol in Biology (SIPB). The PNAT was designed to assess students' knowledge of plant nutrition and consisted of two sections. Section A focused on gathering demographic information, such as age, gender, class, and the school location. Section B contained 30 multiple-choice questions on plant nutrition. Initially, the test consisted of 43 questions, with 70% sourced from past West African Senior Secondary Certificate Examination (WASSCE) questions and 30% developed by the researcher using standard Biology textbooks. To enhance its validity, a panel of three experienced biology teachers with over 10 years of experience in teaching and marking external examinations such as WAEC and NECO, alongside one test construction expert reviewed the instrument. Following their recommendations, the questions were refined, resulting in the reduction of the questions to 30 items. The reliability of the PNAT was determined using the test-retest method. The test was administered to a group of students with similar characteristics but separate from the main study sample. Their scripts were marked and coded for analysis. Reliability test was conducted using Pearson Correlation, yielding a reliability coefficient above 0.83, which was above the acceptable range of 0.70 to 0.80, as recommended for educational research instruments (Mohajan, 2017).

Similarly the SIPB, on the other hand, was developed as a qualitative instrument to gather students' views on the effectiveness of CTCA in enhancing their learning of biology, particularly plant nutrition. Its purpose was to provide insights into students' view about how the CTCA influenced their achievement in biology.

To ensure the validity of the SIPB, a panel of qualitative research experts reviewed the instrument, ensuring that the themes and probes were relevant, clear, and aligned with the study's objectives. Reliability was assessed by piloting the SIPB with a small group of students who shared similar characteristics with the main study sample just as in the case of PNAT, the students' responses were analyzed for consistency and thematic coherence.

Data Collection

The data collection process began with the gathering of quantitative data. Before the study commenced, a pre-test was administered to all students in the two selected schools, one representing the experimental group and the other the control group. This pre-test aimed to assess the students' baseline academic proficiency, ensuring that any changes observed in their performance could be attributed to the intervention rather than pre-existing differences in knowledge.

Following the pre-test, the intervention was carried out over 3 weeks. The experimental group received 4 weeks of instruction using the Conceptual Teaching and Cooperative Approach (CTCA), designed to enhance understanding through cooperative learning and deeper conceptual engagement. Meanwhile, students in the control group were taught using the traditional Lecture Method. This setup enabled a comparison of the impact of CTCA on student outcomes against conventional teaching methods. To add credibility to the findings and avoid relying solely on quantitative data, students' perspectives on their learning experiences and understanding were incorporated.

For the quantitative phase, six students (3 males and 3 females) were selected from the experimental group, ensuring gender balance. The selected students were chosen based on their consistent attendance and active engagement in lessons.

The interviews took place a day after the post-test, in a quiet area of the school to minimize distractions and create a comfortable setting for open dialogue. Students were assured that the interview was not evaluative and that their responses—whether verbal or non-verbal—were equally valued. This approach encouraged candid feedback. Each interview lasted approximately 12 minutes and was recorded for accuracy. Non-verbal cues, such as gestures and head movements, were also noted for additional insight during analysis.

The Students Interview Protocol in Biology (SIPB**)** was used during these interviews to collect qualitative data about the students' views on CTCA approach, particularly on how it influenced their achievement in plant nutrition. The interviews were structured around key questions, such as:

- *Tell us your views about the method (CTCA) used to teach plant nutrition in your class.*
- *How effective is the CTCA in enhancing your achievement in biology?, what are your challenges with the method?*

These interviews provided valuable qualitative insights into how the students perceived the impact of CTCA on their learning experience

Treatment in the Experimental Group (CTCA)

The biology teacher of the experimental group school used as research assistant received training in the use of CTCA. Following a one-week training period, four micro-teaching sessions were conducted in other to show the level of competency of the teacher being trained for the experimental class. Upon completion of the fourth session, the research team evaluated the teacher's proficiency in using the CTCA and determined that the teacher was fluent.

Consequently, the intervention phase of the study was initiated and lasted three weeks. The investigation commenced with a three-week examination of the concepts of Plant Nutrition. During the study period, the experimental cohort received three hours of weekly instruction in plant nutrition. The class teacher, having achieved a high level of proficiency in the culturo-techno-contextual approach, employed this method to teach the subject matter to the students. The aforementioned procedure was executed following a five-stage methodology, as depicted in Figure 3, which can be accessed via http://ctcapproach.com.

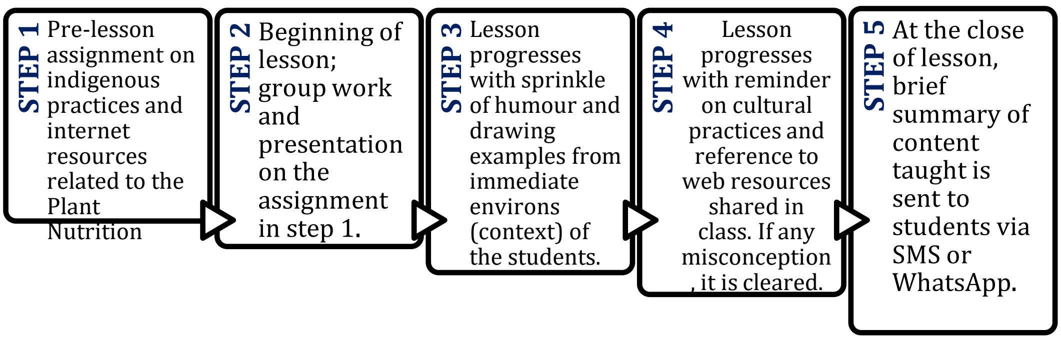

Figure 5. The stages involved in the implementation of CTCA in the classroom (Gbeleyi et al., 2022)

STEP 1: As a pre-lesson activity, the students were informed by the teacher before the actual lesson of the topic to be learned in class, in this case, plant nutrition, and requested that they (a) reflect on indigenous knowledge or cultural practices and beliefs associated with the topic or concept (Plant nutrition). The students were made aware that such reflections are to be shared with others in class when the topic is to be taught; and (b) using their mobile phones or other Internet-enabled devices, search the web for resources relating to the topic (first technology flavour of the approach).

STEP 2: At the start of the lesson and after the introduction by the teacher, students were grouped into mixed-ability, mixed-sex groups to share individual reflections on (a) the indigenous knowledge and cultural practices and beliefs associated with the topic; and (b) summaries of ideas obtained from web resources. All such cultural and web-based reflections were documented and presented to the whole class by the group leaders. The teacher wraps up by sharing his/her indigenous knowledge and cultural practices associated with the topic.

STEP 3: The teacher progresses the lesson, drawing practical examples from the immediate surroundings of the school. Such examples can be physically observed by students to make the concept real and less abstract. One way to conceptualize plant nutrition was to explain that the Yoruba man believes that he should not plant inside his house because the plants require sunlight and rainfall. Even when they plant inside the house it is placed at the window for sunlight and constantly watered. This is the “context” flavour of the approach.

STEP 4: As the lesson further progressed, the class was reminded of the relevance of the indigenous knowledge and cultural practices documented by the groups for a meaningful understanding of plant nutrition. Areas of misconceptions associated with cultural beliefs were cleared by the teacher. For instance, the misconception of students that in some States like Osun and Oyo, the productivity of crops is linked to spiritual or ancestral blessings. Poor yields might be attributed to spiritual displeasure rather than inadequate nutrient management or poor soil conditions.

STEP 5: At the close of the lesson, the teacher sends a maximum 320-character summary of the lesson (two pages in SMS) via WhatsApp to all students. After the first lesson, student group leaders were saddled with the responsibility of composing the summaries and sending them to the WhatsApp group. This is another technological flavour of the approach.

Cultural Practices Associated with Plant Nutrition

Some of the cultural practices associated with Plant Nutrition in the South-West which was used to teach the concept of plant nutrition:

a. **Use of Organic Manure**

Figure 6. Image of cattle dung (Igbe Maalu) (Alamy.com)

The Yoruba farmers traditionally use organic materials like animal dung (cattle), compost, and ash to enrich soil fertility. These natural fertilizers are believed to enhance soil productivity and are often applied during land preparation. These organic materials applied by the farmers serve as nutrients for crops aside from carbon dioxide and water which is the basic need for photosynthesis. Also, ash from burnt wood or crop residues is spread over farmland to improve soil fertility. This is believed to ward off evil spirits and pests while enhancing plant growth due to its nutrient content, particularly potassium. The use of cattle dung provides manure that nourishes the soil. This was used to also explain how nutrient-rich soil supports plant growth and photosynthesis.

b. Rain-Making Ceremonies (Adura Ojo or Ológbojò):

Figure 7. Picture of children bathing under the rain (Olubayo Stephen 2023)

Rain-making ceremonies are common in Yoruba culture and emphasize the importance of rain in sustaining crops and life. This practice is used to explain photosynthesis that rain provides water, a critical ingredient for the photosynthesis process. Students were able to understand how water absorbed by plant roots is used to produce food and energy.

c. Tree Worship or Sacred Trees (Igi Agba Orisa):

Figure 8. Picture of Igi Nla (Oyediran Awolowo Damilare 2018)

Certain trees, such as the Iroko or Baobab, are considered sacred in Yoruba culture. These trees were used to explain the role of chlorophyll and how leaves trap sunlight to facilitate photosynthesis, leading to the tree's longevity and significance in its environment.

d. Yoruba Proverbs on Agriculture (Owe Yoruba):

Figure 9. Tales by Moonlight (The Cable.ng)

This image was used to depict students being taught African folklore which includes several proverbs. One example of such a proverb is **"Eweko ki n dagba**

l'aiye orun" (Plants cannot grow without the sun) was used to introduce the role of sunlight in photosynthesis. Such sayings resonate with students' cultural understanding, making the concept more relatable as sunlight a key part of photosynthesis.

Lesson in the Control Group

As with the experimental group, the teacher in the control group was retained for consistency throughout the study. This teacher taught the control group the same concept of plant nutrition, but without incorporating CTCA. The teaching process followed a four-step approach:

Step 1: The teacher introduced the topic of plant nutrition to the students.
Step 2: The concept of plant nutrition was explained in detail.
Step 3: Students were allowed to ask questions at the end of the lesson.
Step 4: The teacher summarized the lesson and assigned homework.

Data Analysis

Mean and standard deviation were used to interpret the research question, while Analysis of Covariance (ANCOVA) was selected as the most suitable statistical method. ANCOVA accounted for a single dependent variable (achievement) and controlled initial group differences by using pre-test scores as a covariate. Qualitative data were analyzed using an interpretative theme method. Audio recordings were replayed multiple times, transcribed verbatim, and rigorously reviewed to identify emergent themes relevant to the study's findings and interpretation.

3. Results and Discussion

The major quest of our study was to investigate if CTCA enhances the achievement of students in Plant Nutrition. The quantitative dataset underwent preliminary tests to test the normality of the population and homogeneity of variance to verify that the data satisfied the assumptions of the statistical tool ANCOVA. The findings indicate that the data did meet the normality assumptions of the Shapiro-Wilk test ($F(88) = 0.76$; $p > .05$). The findings indicate that the dataset satisfied the assumption of normality as assessed by the Shapiro-Wilk test since the p-value is greater than 0.05.

Research question: Is there is a difference in the achievement of students taught Plant Nutrition using the Culturo-techno- contextual approach and lecture method?

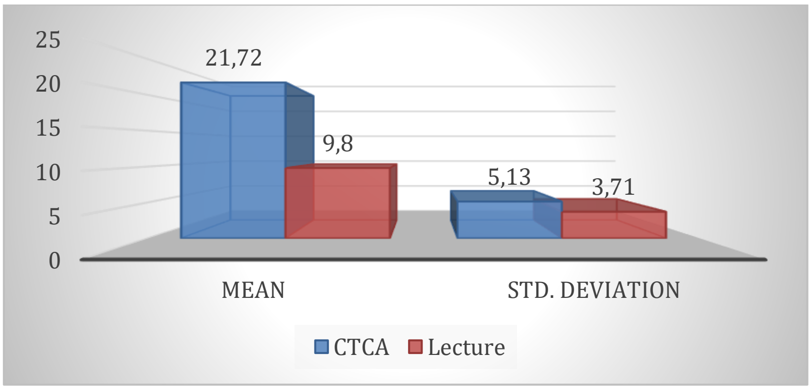

Figure 10. Mean and standard deviation of students in the CTCA group and Lecture group

The descriptive statistics revealed that the experimental group had a higher mean achievement score (21.72) compared to the control group (9.80) and also the experimental group has a higher standard deviation (5.13) compared to the control group (3.71).

To determine if this difference was statistically significant and not merely due to chance, we conducted further inferential statistical tests. The results of these tests are presented in Table 2.

Table 1. Test of significance of achievement between the experimental group (CTCA) and control group (Lecture method)

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4989.97[a]	2	2494.98	125.51	.00	.65
Intercept	2935.84	1	2935.84	147.69	.00	.52
Pre_Achievement	119.87	1	119.87	6.03	.02	.04
Strategies	4989.86	1	4989.86	251.02	.00	.65
Error	2683.57	135	19.88			
Corrected Total	7673.54	137				

a. R Squared = .650 (Adjusted R Squared = .645)

The table 1 presents the results of an Analysis of Covariance (ANCOVA) conducted to examine whether there is a statistically significant difference in the achievement of students taught Plant Nutrition using the Culturo-Techno Contextual Approach (CTCA) and the Lecture Method. The analysis revealed that the overall model was statistically significant, $F(1,135) = 251.02$; $p<0.05$ indicating that the combination of pre-test scores and teaching strategies explained a significant portion of the variance in post-test achievement. Also, the partial eta squared estimate indicates that the treatment accounted for 0.65: This indicates that the teaching strategy accounts for a large effect size of 65% of the variance in post-achievement scores. The study revealed a large effect size, indicating that the differences are substantial in real-world contexts

Given that the p-value for teaching strategies is less than 0.05, the null hypothesis—which posited no significant difference in achievement between the two methods—is rejected. Specifically, the results suggest that students taught using the Culturo-Techno Contextual Approach (CTCA) performed significantly better than those taught using the Lecture Method.

To add credibility to the findings and avoid relying solely on quantitative data, students' views about CTCA were sought through in-depth interviews. The excerpt of the interviews is presented in Table 2 below:

Table 2. Excerpt from Students' Interviews

Theme	Summary of Finding
Views of students about CTCA and its impact on achievement.	*"The method is really helpful to me, my performance in biology will to the teaching method that was used and I don't have to cram again (Student A, male);* *The class was interesting because the class was interactive, yes, it is really fast but we need to see our cultural things" (Student C, female);* *"The method makes me think and explain things better...it encourages me more to read, I think it is interesting " (Student B, female);* *"with how we chatted in the class and relate our teaching to things around us, I understand plant nutrition better with some funny and strange objects(laughs…)" (Student D, female):* *"To me sir, I can no longer struggle to remember things and I have what I can think about to remind me what we have been taught, please bring indigenous objects to class for better performmance, "(Student E male);* *"I am happy with the method, it helped me understand, and appreciate the lessons"(Student F, male).*

Table 2 shows that the Culturo-Techno Contextual Approach (CTCA) was generally well received by the students. A significant 80% of the students expressed positive views about the method, agreeing that it effectively enhanced their understanding of plant nutrition as taught by their teacher. However, a small number of students suggested incorporating concrete, indigenous materials to better illustrate certain concepts related to plant nutrition.

Discussion

Primarily, this study aimed to determine if CTCA could improve student achievement in plant nutrition. The results showed a significant advantage for students taught with CTCA compared to those taught with the lecture method. As one student commented, *"The method makes me think and explain things better... it encourages me more to read, I think it is interesting"* (Student B, female), suggesting that the approach helped them to think critically and engage with the material on a deeper level. This indicates that CTCA's culturally relevant and technology-integrated nature is more effective in teaching concepts related to plant nutrition. The findings are consistent with previous research by Abdulhadi et al. (2023), Ademola et al. (2023), Akintoye et al. (2023), Adam et al. (2024a), Onowugbeda et al. (2023), Adam et al. (2024b), Oladejo et al. (2023b), and Gbeleyi et al. (2022), which found that CTCA has proven to be an effective approach in enhancing student achievement in biology and other science subjects.

We posit that students taught using the CTCA approach outperformed their counterparts in the control group because the culturally tailored content allowed them to leverage familiar cultural knowledge in plant nutrition and practices shared within their groups. One student shared, *"With how we chatted in the class and relate our teaching to things around us, I understand plant nutrition better with some funny and strange objects (laughs...)"* (Student D, female). Another added, *"I am happy with the method, it helped me understand, and appreciate the lessons"* (Student F, male), indicating that the approach's integration of cultural and contextual knowledge made the learning experience more engaging and relatable. By aligning the teaching of plant nutrition with their diverse cultural backgrounds and lived experiences, students could engage more deeply with the subject matter. This cultural resonance enhanced their understanding and provided a distinct advantage in grasping and applying key concepts.

The learners' contextual experiences significantly contributed to the experimental group (CTCA) outperforming the control group (Lecture Method). One student explained, *"To me, sir, I can no longer struggle to remember things and I have what I can think about to remind me what we have been taught, please bring indigenous objects to class for better performance"* (Student E, male). This suggests that real-world, culturally relevant examples allowed students to retain and relate information better. Much of the cultural knowledge utilized in the CTCA group was drawn from familiar, real-life experiences within their environment. For instance, the group that presented at the rain-making ceremony had witnessed this ritual performed annually in their community. This contextual familiarity likely enhanced their understanding, as they could easily relate the importance of rain—a critical element in their cultural practice—to its scientific role in photosynthesis. This alignment between cultural context and scientific concepts provided a relatable and engaging learning experience, reinforcing their grasp of the subject matter.

Group work also introduces an element of accountability. As one student shared, *"The class was interesting because the class was interactive; yes, it is really fast, but we need to see our cultural things"* (Student C, female), highlighting that the collaborative nature of CTCA encouraged students to participate actively. Students feel responsible for contributing to their group's success, which often leads to greater commitment and higher levels of participation. The social aspect of group activities makes the classroom environment more dynamic and less formal, encouraging students to interact freely and confidently. This enhanced engagement is another reason for the experimental group's improved performance compared to the control group.

Furthermore, Ausubel's meaningful learning theory expands on Vygotsky's viewpoint by emphasizing the importance of connecting new information to existing cognitive structures. Ausubel contended that rote learning, in which material is memorised without reference to prior knowledge, is less effective and lasting than meaningful learning. The usage of advanced organisers in the CTCA classroom, such as pre-activity assignments given to the students before the class, concept maps aided students in connecting their past knowledge to new plant nutrition principles. These organisers provided a cognitive framework that enabled learners to better learn new knowledge while avoiding cognitive overload. By explicitly linking new concepts to existing schemas, the CTCA approach fostered a more profound and lasting understanding of plant nutrition, ensuring that learning was not merely superficial but deeply integrated into the students' cognitive framework. This combination of social interaction within the ZPD and meaningful learning through advance organizers provided a powerful synergy, contributing to the observed effectiveness of CSCA in promoting fair and impactful learning outcomes.

The CTCA clearly improves cognitive processes and dramatically increases classroom participation. By strategically assigning pre-class tasks that require students to explore diverse cultural perspectives at home and then organising them into collaborative groups during class time, the CTCA effectively fosters a multifaceted learning experience for the learner because they share different perspectives. This method of teaching (CTCA) not only promotes critical thinking by encouraging students to analyse issues from multiple overviews, but it also promote active involvement by having students share their perceptions and engage in solid discussions, as opposed to the lecture method, which does not involve learners in the organisation of the learning process. Furthermore, the CTCA's collaborative group work promotes deeper learning through peer sessions, knowledge sharing, and mutual building of understanding. These carefully developed strategies work together to create a more active and interactive classroom atmosphere, changing passive learning into an active and engaging experience. This increased engagement and cognitive stimulation leads to greater student accomplishment, as seen by the statistically significant changes observed in the ANCOVA results, which provide convincing empirical evidence of the CTCA's efficacy.

Educational Implications

The significant positive impact of the Culturo-Techno Contextual Approach (CTCA) on student achievement suggests that incorporating cultural, technological, and contextual elements into the teaching process can greatly enhance learning outcomes. Also, relating content to students' cultural backgrounds makes the material more relevant and memorable, which enhances their learning experience. CTCA also effectively stimulates cognitive processes. By assigning tasks that require students to explore cultural perspectives before class, this approach activates prior knowledge, enhancing understanding and retention of new information. Engaging with cultural perspectives requires critical thinking and analysis, fostering deeper learning. Moreover, CTCA increases classroom engagement by grouping students. Group activities facilitate collaborative learning, allowing students to work together and learn from each other. This method requires active participation, keeping students engaged and attentive. The social interaction within groups can boost motivation and interest in the subject matter, making the learning experience more dynamic and interactive.

4. Conclusion

The study reveals a significant impact of the Culturo-Techno Contextual Approach (CTCA) on student achievement in Plant Nutrition compared to traditional lectures. This highlights the need for innovative methods in Lagos senior secondary schools. CTCA integrates cultural, technological, and contextual elements, stimulating cognitive processes and fostering classroom engagement. Pre-class tasks activate prior knowledge, encourage critical thinking, and enhance retention, while collaborative activities boost motivation, engagement, and peer learning.

These findings emphasize the importance of adopting CTCA in biology education, as it improves academic performance and makes learning more relevant. By integrating CTCA, educators can create dynamic, interactive classrooms that foster deeper understanding of Plant Nutrition and other biological concepts. This forward-thinking approach ensures better learning experiences, improved outcomes, and greater student appreciation for biology.

Ethical Consideration

Before the study began, we obtained permission from the relevant educational institutions (African Centre for Innovative and Transformative STEM Education and the Principals of the Schools Used) to conduct our research on their premises. Additionally, all participants provided written consent by signing a consent form, confirming their voluntary participation. We clearly explained the study's objectives to the participants and assured them of the confidentiality of their responses, which would be used solely for research purposes. We emphasized to both school officials and participants that participation was entirely voluntary and that they could withdraw from the study at any time without giving a reason. Throughout the study, we ensured that no participant was subjected to any form of harm or exploitation.

Limitations and Future Directions

While this study has limitations, including the relatively small sample size and the specific subject content addressed, which restrict the generalizability of our findings, we anticipate that implementing this approach in other classrooms with similar subject characteristics could lead to significantly improved learning outcomes in biology. Moreover, this study holds valuable implications for both research and practice. For researchers, we recommend conducting further studies on the application of CTCA in biology, expanding the scope beyond the topic of plant nutrition, with larger sample sizes and longer study durations. For STEM educators and practitioners, this study serves as a call to reevaluate their teaching methods and adopt strategies that integrate cultural and contextual considerations of the learners into the teaching and learning process.

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