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Revolutionizing Biology Learning: A Study on the Culturo-Techno-Contextual Approach (CTCA) and Its Rapid Impact on Student Achievement in Nutrient Cycling

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ABSTRACT

This study investigates the impact of the Culturo-Techno-Contextual Approach (CTCA) on student achievement in nutrient cycling, a critical topic in biology education, within senior secondary schools in Lagos, Nigeria. The research aims to address the persistent challenges in biology education, such as poor student performance, inadequate teaching resources, and over-reliance on rote memorization. The study employed an explanatory sequential mixed-method design, combining quantitative and qualitative approaches. Two intact classes were selected, with one group taught using CTCA and the other using the traditional lecture method. The Nutrient Cycling Achievement Test (NCAT) was used to assess student performance, while qualitative data were gathered through student interviews using the Students Biology Interview Protocol (SBIP). Results revealed that students in the CTCA group outperformed their counterparts in the control group [$F(1,134) = 1655.16$, $p < .05$]. The qualitative findings highlighted that students found CTCA more engaging, relatable, and effective in enhancing their understanding of nutrient cycling. The study concludes that integrating cultural, technological, and contextual elements into teaching significantly improves learning outcomes, fostering critical thinking and deeper understanding. The findings suggest that CTCA is a viable alternative to traditional teaching methods, particularly in resource-constrained settings, and recommend its broader adoption in biology education to enhance student achievement and engagement.

Keywords: Culturo-Techno-Contextual Approach (CTCA), Nutrient Cycling, Biology Education, Student Achievement, Mixed-Method Design.

INTRODUCTION

Biology, as a core science subject, plays a pivotal role in the Nigerian senior secondary school curriculum. It provides students with a foundational understanding of living organisms, their interactions, and the environment, which is essential for addressing global challenges such as health, food security, and climate change. In Nigeria, Biology is a compulsory and critically important subject for students in the science stream at the senior secondary school level. This requirement is firmly established in the national education policy, as outlined in the Federal Ministry of Education's (2013) Senior Secondary School Curriculum for Biology, which designates Biology as a core science subject alongside Chemistry and Physics. The significance of Biology is further reinforced by major examination bodies in Nigeria. Both the West African Examinations Council (WAEC) and the National Examinations Council (NECO) mandate that science students take Biology as part of their Senior School Certificate Examinations (SSCE) (Okebukola, 2015). Additionally, for university admissions, the Unified Tertiary Matriculation Examination (UTME) administered by the Joint Admissions and

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Matriculation Board (JAMB) requires Biology for most science-based degree programs, particularly in fields such as Medicine, Pharmacy, Biochemistry, and Agriculture (Ajayi, 2019).

While there are limited exceptions—such as students focusing solely on Physics, Chemistry, and Further Mathematics—opting out of Biology significantly restricts their university course options (Ogunniyi, 2016). Thus, for the vast majority of science students in Nigeria, Biology remains an indispensable subject that shapes their academic and career trajectories. Despite its importance, the teaching of biology in Nigerian senior secondary schools faces several challenges that hinder effective learning outcomes. One major issue is the lack of adequate teaching resources. Many schools lack well-equipped laboratories, modern teaching aids, and up-to-date textbooks, which are critical for practical and theoretical understanding of biological concepts (Okebukola, 2015). Practical sessions, which are essential for reinforcing theoretical knowledge, are often neglected due to insufficient equipment and reagents. This limits students' ability to develop critical thinking and problem-solving skills, which are central to scientific inquiry. Furthermore, the over-reliance on traditional lecture methods, rather than student-centered approaches such as inquiry-based learning, reduces students' interest and engagement in the subject (Aina, 2017).

Another challenge is the quality of biology teachers. While many teachers possess the required qualifications, some lack the pedagogical skills and content knowledge necessary to deliver the subject effectively. Continuous professional development programs for teachers are often inadequate, leaving them ill-equipped to adapt to modern teaching methodologies (Ajayi, 2019). Additionally, large class sizes in many schools make it difficult for teachers to provide individualized attention to students, further exacerbating the problem of poor academic performance in biology.

The Nigerian educational system also places a heavy emphasis on examinations, which often leads to a focus on rote memorization rather than conceptual understanding. This approach undermines the development of critical thinking and practical skills, which are essential for students pursuing careers in science-related fields (Ogunniyi, 2016). To address these issues, there is a need for curriculum reforms that emphasize hands-on learning, critical thinking, and the integration of technology in biology education.

The biology curriculum in Nigeria is designed to provide senior secondary school students with a comprehensive understanding of living organisms, their functions, and their interactions with the environment. It is a core subject in the science stream and is essential for students aspiring to pursue careers in medicine, agriculture, biotechnology, and environmental sciences. The curriculum, developed by the Nigerian Educational Research and Development Council (NERDC), aims to foster scientific literacy, critical thinking, and practical skills among students (Federal Ministry of Education, 2013). However, despite its well-structured objectives, the implementation of the biology curriculum faces several challenges that affect its effectiveness.

The biology curriculum is divided into three years (SS1, SS2, and SS3) and covers a wide range of topics, including cell biology, genetics, ecology, evolution, and human physiology. It emphasizes both theoretical knowledge and practical skills, with the goal of equipping students with the ability to apply biological concepts to real-world situations (Okebukola, 2015). Practical activities, such as microscopy, dissection, and field studies, are integral to the curriculum, as they help students develop observational and analytical skills. However, many schools lack the necessary laboratory equipment and resources to conduct these activities effectively, which limits students' practical exposure (Aina, 2017).

One of the strengths of the biology curriculum is its alignment with global scientific standards and its focus on addressing local and national issues. For instance, topics such as disease prevention, conservation, and sustainable agriculture are included to reflect Nigeria's health and environmental challenges (Ajayi, 2019). This contextual approach makes the curriculum relevant to students' lives and encourages them to contribute to solving societal problems. However, the curriculum's heavy content load and the pressure to cover all topics within a limited time frame often lead to superficial teaching and learning, with an overemphasis on rote memorization rather than deep understanding (Ogunniyi, 2016).

Another issue is the lack of adequate teacher training and professional development opportunities. Many biology teachers struggle to implement the curriculum effectively due to insufficient pedagogical skills and outdated teaching methods (Okebukola, 2015). Additionally, the curriculum's reliance on traditional assessment methods, such as written examinations, often discourages creativity and practical application of knowledge. To address these challenges, there is a need for continuous review and updating of the curriculum to incorporate modern teaching strategies, such as inquiry-based learning and the use of technology (Federal Ministry of Education, 2013).

The biology curriculum in Nigeria is well-structured and relevant to both national and global scientific needs. However, its implementation is hindered by inadequate resources, teacher training, and assessment methods. To maximise its potential, stakeholders must invest in infrastructure, teacher development, and innovative teaching approaches. By doing so, the curriculum can effectively prepare students for higher education and careers in science, fostering a culture of scientific inquiry and problem-solving in Nigeria.

Biology is one of the most popular science subjects offered by Nigerian students in external examinations, particularly the West African Senior School Certificate Examination (WASSCE) and the National Examination Council (NECO). Its prominence stems from its status as a prerequisite for admission into tertiary institutions, especially for courses in medicine, pharmacy, agriculture, and environmental sciences (Federal Ministry of Education, 2013). Despite its popularity, the enrollment trends and performance of students in biology examinations reveal significant challenges in the teaching and learning of the subject.

Over the years, there has been a steady increase in the number of students enrolling for biology in external examinations. This is largely due to the subject's relevance to a wide range of career paths and its compulsory status for science students in senior secondary schools (Okebukola, 2015). However, while enrollment figures are high, the performance of students in biology examinations has been consistently poor. For instance, statistics from the West African Examinations Council (WAEC) indicate that a significant percentage of candidates fail to achieve credit passes (A1-C6) in biology, which is a requirement for university admission (WAEC, 2020). This trend highlights the gap between enrollment and academic achievement in the subject.

Several factors contribute to the poor performance of students in biology examinations. One major issue is the inadequate preparation of students, often resulting from a lack of qualified teachers, insufficient teaching resources, and poorly equipped laboratories (Aina, 2017). Many schools struggle to provide the necessary practical experiences, such as experiments and field studies, which are critical for understanding biological concepts and performing well in examinations. Additionally, the emphasis on rote memorization rather than conceptual understanding further undermines students' ability to apply their knowledge to examination questions (Ogunniyi, 2016).

Another challenge is the mismatch between the biology curriculum and the examination syllabi. While the curriculum is designed to promote critical thinking and practical skills, the examination system often prioritizes theoretical knowledge and memorization (Ajayi, 2019). This disconnect discourages innovative teaching methods and places undue pressure on students to cram information rather than develop a deep understanding of the subject. Furthermore, the high stakes associated with external examinations exacerbate students' anxiety, which can negatively impact their performance.

To address these issues, there is a need for reforms in both the teaching of biology and the examination system. Investments in teacher training, laboratory equipment, and modern teaching aids can improve the quality of biology education and better prepare students for examinations (Okebukola, 2015). Additionally, incorporating more practical and application-based questions in external examinations can encourage a shift from rote learning to critical thinking and problem-solving. Collaborative efforts between the government, examination bodies, and educators are essential to ensure that the high enrollment in biology translates into improved academic outcomes.

Biology remains a highly enrolled subject in Nigerian external examinations, the persistent poor performance of students underscores the need for systemic reforms. Addressing the challenges of inadequate resources, teacher quality, and examination practices can enhance students' understanding of biology and their performance in examinations, ultimately contributing to the development of a scientifically literate society.

Achievement in biology among Nigerian students has been a subject of concern for educators, policymakers, and stakeholders in the education sector. Biology, being a core science subject, is essential for students pursuing careers in medicine, agriculture, environmental sciences, and other science-related fields. However, despite its importance, the performance of students in biology, both in internal assessments and external examinations, has been consistently poor, reflecting systemic challenges in the teaching and learning of the subject (Federal Ministry of Education, 2013).

One of the key indicators of achievement in biology is the performance of students in external examinations such as the West African Senior School Certificate Examination (WASSCE) and the National Examination Council (NECO). Over the years, statistics from these examination bodies have shown that a significant percentage of students fail to achieve credit passes (A1-C6) in biology, which is a requirement for admission into tertiary institutions (WAEC, 2020). For instance, the WAEC Chief Examiners' Report often highlights common areas of weakness, such as genetics, ecology, and practical biology, where students perform poorly due to a lack of understanding and inadequate preparation (Okebukola, 2015).

Several factors contribute to the low achievement levels in biology. A major issue is the lack of qualified and motivated teachers. Many biology teachers lack the necessary pedagogical skills and content knowledge to deliver the subject effectively, which negatively impacts students' understanding and performance (Ajayi, 2019). Additionally, the shortage of teaching resources, such as well-equipped laboratories, textbooks, and modern teaching aids, limits students' exposure to practical activities and hands-on learning, which are critical for mastering biological concepts (Aina, 2017).

Another factor is the overemphasis on rote memorization rather than conceptual understanding. The Nigerian education system places a heavy focus on examinations, which often leads to a "cram-and-pass" approach rather than a deep understanding of the subject matter (Ogunniyi, 2016). This approach undermines students' ability to apply their knowledge to solve problems or answer higher-order thinking questions, which are increasingly emphasized in modern examinations. Furthermore, large class sizes and inadequate instructional time make it difficult for teachers to provide individualized attention to students, further exacerbating the problem of poor achievement.

To improve achievement in biology, there is a need for comprehensive reforms in the education sector. Investments in teacher training, provision of laboratory equipment, and development of innovative teaching methods can enhance the quality of biology education (Okebukola, 2015). Additionally, curriculum reforms that emphasize critical thinking, problem-solving, and practical skills can better prepare students for examinations and real-world applications. Collaborative efforts between the government, schools, and stakeholders are essential to address these challenges and improve students' performance in biology.

While biology is a critical subject for Nigeria's scientific and economic development, the persistent low achievement levels among students highlight the need for urgent reforms. By addressing the challenges of teacher quality, resource availability, and teaching methodologies, Nigeria can improve students' understanding of biology and their performance in examinations, ultimately fostering a generation of scientifically literate individuals capable of contributing to national development.

Nutrient cycling is a fundamental ecological process that describes the movement and exchange of organic and inorganic matter back into the production of living organisms. It involves the recycling of essential elements such as carbon, nitrogen, water, through biotic and abiotic components of ecosystems. This process ensures the availability of nutrients for plant growth, which forms the basis of food chains and sustains life on Earth (Polis, Anderson & Holt 1997). In biology education, nutrient cycling is a critical topic that helps students understand the interconnectedness of ecosystems and the importance of maintaining ecological balance.

The study of nutrient cycling provides students with insights into key biological processes such as photosynthesis, respiration, decomposition, and nitrogen fixation. For instance, the carbon cycle illustrates how carbon moves through the atmosphere, plants, animals, and soil, highlighting the role of photosynthesis in converting carbon dioxide into organic matter and the role of respiration in releasing it back into the atmosphere (Rutledge et al., 2010). Similarly, the nitrogen cycle demonstrates how nitrogen is converted into various forms, such as ammonia and nitrates, which are essential for plant growth. These cycles are not only central to ecological studies but also have significant implications for addressing global issues such as climate change, soil fertility, and pollution (Smith et al., 2016).

Teaching nutrient cycling in biology is important because it fosters an understanding of sustainability and environmental stewardship. By learning about nutrient cycles, students appreciate the delicate balance of ecosystems and the impact of human activities, such as deforestation, industrialization, and excessive use of fertilizers, on these cycles (Ryan, 2019). This knowledge equips students with the tools to think critically about environmental conservation and to propose solutions to ecological problems. Furthermore, nutrient cycling serves as a practical example of how biological concepts are applied in real-world contexts, making the subject more engaging and relevant to students.

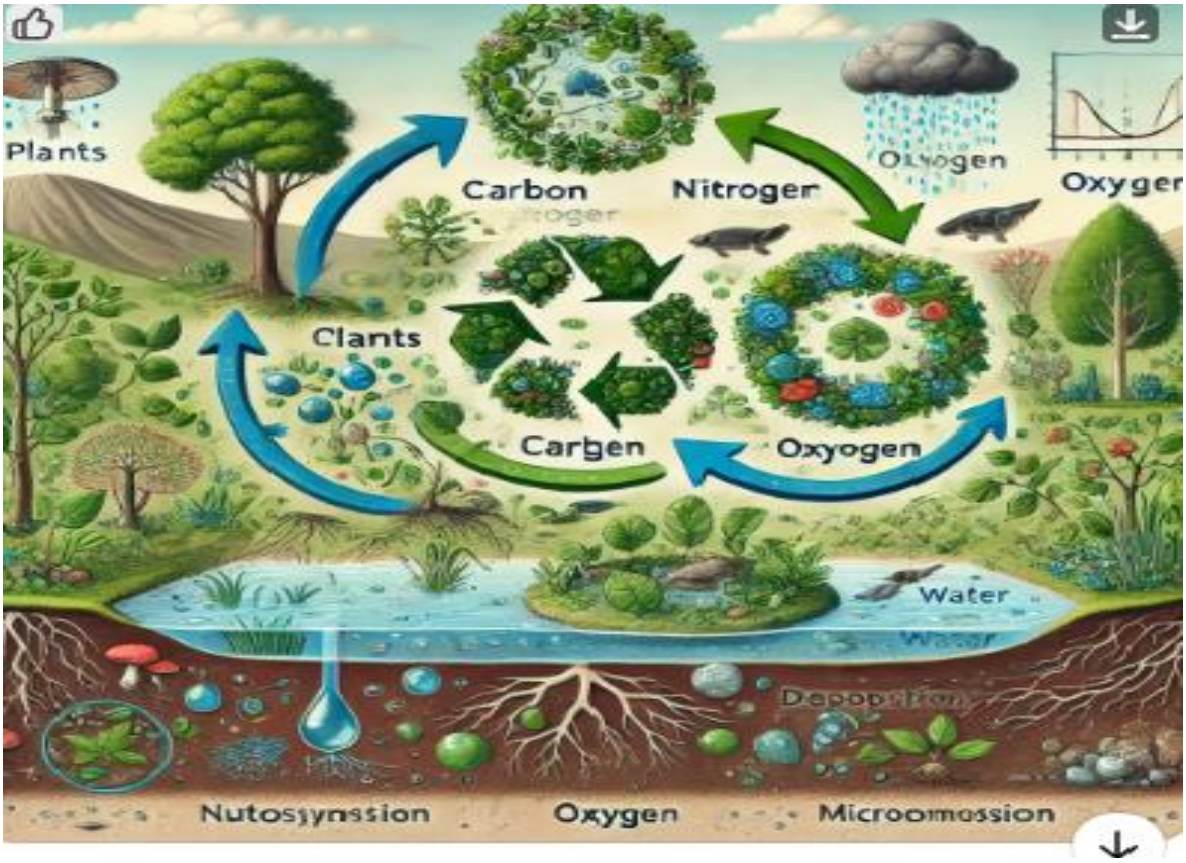

Figure 1: image of different nutrient cycles

Incorporating nutrient cycling into the biology curriculum also enhances students' scientific literacy and problem-solving skills. Practical activities, such as modelling nutrient cycles, conducting experiments on decomposition, or analyzing case studies on eutrophication, provide hands-on learning experiences that reinforce theoretical knowledge (Aina, 2017). These activities encourage students to think analytically and to connect biological concepts with environmental and societal issues. Additionally, the topic provides opportunities for interdisciplinary learning, linking biology with chemistry, geography, and environmental science.

The teaching of nutrient cycling in biology is essential for several reasons. First, it helps students understand the intricate relationships within ecosystems and the interdependence of organisms (Moran 2022). By learning how nutrients flow through ecosystems, students can appreciate the importance of conservation and sustainable environmental practices. Additionally, nutrient cycling provides a scientific foundation for understanding issues such as climate change, deforestation, and pollution, which are pressing global challenges (Raven & Wagner 2021).

Furthermore, integrating nutrient cycling into biology education enhances critical thinking and problem-solving skills. Students engage in practical investigations, such as analyzing soil composition, measuring carbon footprints, and examining the impact of human activities on nutrient cycles (Sher 2022). These hands-on activities reinforce theoretical concepts and make learning more engaging.

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Nutrient cycling is a vital topic in biology that underscores the interdependence of living organisms and their environment. Its inclusion in the biology curriculum not only deepens students' understanding of ecological processes but also promotes environmental awareness and critical thinking. By teaching nutrient cycling, educators can inspire students to become informed and responsible citizens who contribute to the preservation of natural resources and the sustainability of ecosystems.

Before Nigeria's independence, one of the primary methods used to teach biology was the lecture approach, which involved merely introducing topics or concepts (Tukur, Nurulwahida, Hi & Madya, 2019). However, this method had significant limitations, as students were not actively involved in the learning process and had little opportunity to construct their own knowledge. Research has shown that the lecture method is relatively ineffective, producing limited results due to its passive nature, which restricts student engagement (Obro, 2022). Despite its drawbacks, many teachers, trainers, and lecturers continue to rely on lectures as a primary means of delivering information. Depending on the clarity of the material, the presenter's delivery style, and the relevance of the topic, lectures can either be informative, monotonous, or overwhelming. Because this approach primarily involves one-way communication with minimal audience participation, it often results in confusion, information loss, and poor retention. Consequently, there is a need for more effective teaching strategies that can improve learning outcomes. One such approach is the Culturo-Techno-Contextual Approach (CTCA), which fosters active student participation, critical thinking, and practical application of scientific concepts.

CTCA and Science Learning

The Culturo-Techno Contextual Approach (CTCA) emerged after more than 40 years of searching for an effective tool to overcome barriers to meaningful science learning. Various teaching methods, such as cooperative learning, concept mapping, discovery learning, demonstration, argumentation, mastery learning, and vee diagramming, have been shown to enhance students' understanding of scientific concepts. However, individually or in combination, these methods have not been able to consistently promote deep and meaningful learning, especially in the presence of contextual challenges. The need for an approach that fosters significant learning and improves students' performance in both school and public examinations led to the development of the CTCA (Okebukola, 2020).

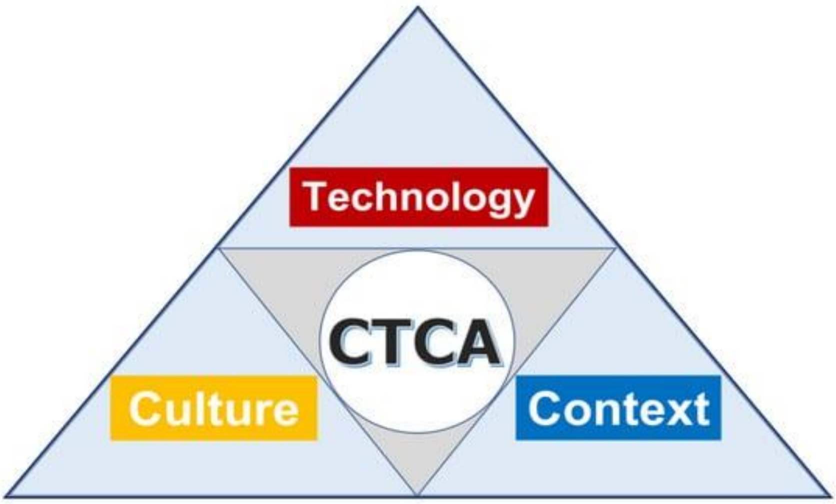

Figure 2: The three Elements of CTCA (Source: Oladejo et al., 2023)

The Culturo-Techno Contextual Approach (CTCA) is designed to eliminate common barriers to meaningful science learning. These barriers include the fear of science due to its complex terminology and mathematical focus, inadequate teaching and learning resources, the abstract nature of certain concepts, and the misconception that science is only for highly gifted individuals. CTCA addresses these challenges by incorporating three essential frameworks: (a) the cultural context, which aligns with the learners' familiar environment; (b) technology mediation, which enhances teaching and learning through digital tools; and (c) the locational context, which recognizes the unique characteristics of each school and promotes the use of locally relevant examples in science lessons (Okebukola, 2020). Rooted in constructivist learning theories, CTCA emphasizes that students

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develop their understanding through direct experiences and reflective thinking, in contrast to the traditional lecture-based approach that often limits student engagement. By implementing CTCA in biology education, teachers can foster dynamic and interactive learning environments where students actively explore, question, and apply scientific knowledge in meaningful ways (Ige et al., 2025).

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).

Additionally, the Culturo-Techno Contextual Approach (CTCA) highlights the significance of the learning environment, emphasizing that students learn most effectively when they can engage with peers and instructors, receive constructive feedback, and reflect on their learning experiences. In Lagos senior secondary schools, fostering such an environment may involve integrating technology, making creative use of available resources, and encouraging a culture of inquiry and collaboration among students. This comprehensive approach not only improves academic performance but also equips students with the skills needed for future educational and career pursuits (Adam, 2019). Given the ever-evolving nature of biological sciences and rapid advancements in related fields, it is essential for students to develop critical thinking and problem-solving skills rather than rely solely on rote memorization.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.

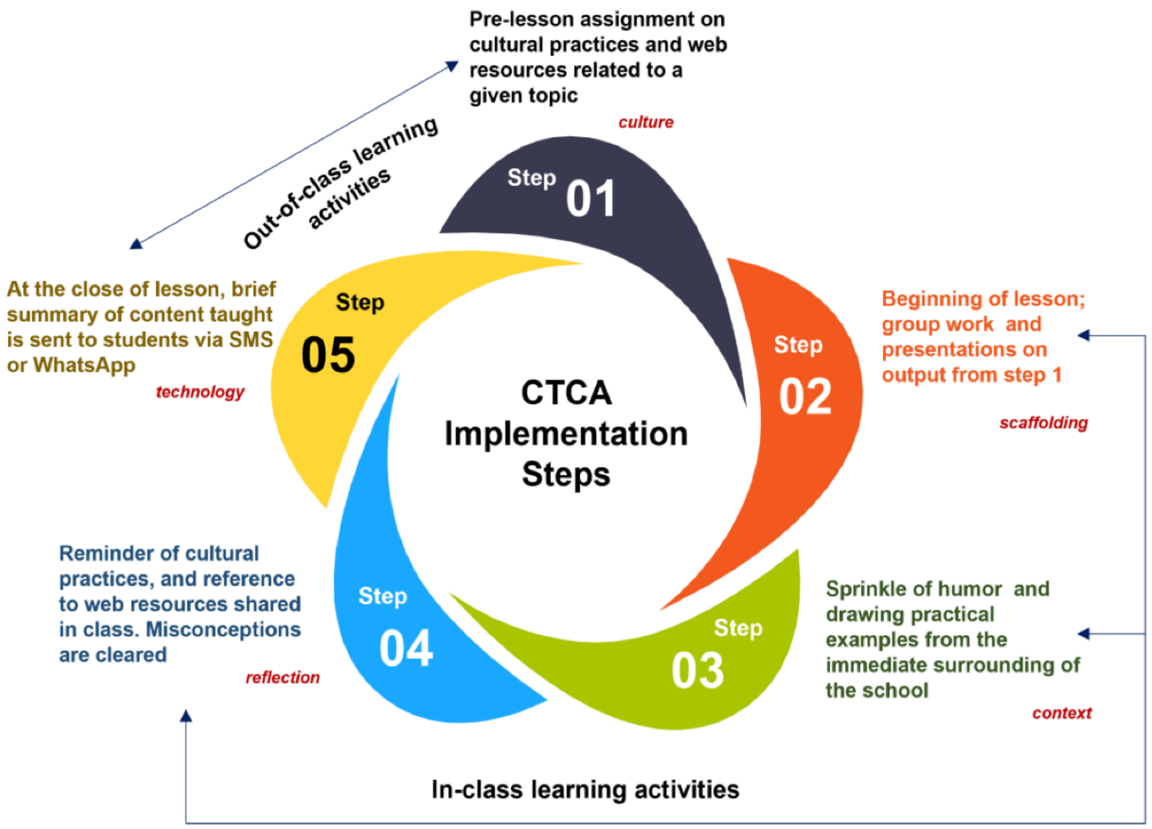

Figure 3: CTCA Implementation steps (Source: Oladejo et al., 2023)

The integration of the Culturo-Techno-Contextual Approach (CTCA) framework into biology education in Lagos senior secondary schools aims to revolutionize the teaching and learning process. By shifting away from traditional lecture-based methods and embracing a more interactive, student-centred approach, educators can better prepare students with the knowledge, skills, and attitudes needed to excel academically and make meaningful contributions to society. The decision to focus on the CTCA framework for enhancing biology learning in Lagos is driven by the pressing need to improve educational outcomes in the region. Conventional teaching methods (Lecture Method) have proven inadequate in engaging students and fostering a deep understanding of complex biological concepts, particularly in topics like plant nutrition, where both theoretical and practical knowledge are essential. By adopting the CTCA framework, educators can overcome these limitations and create a more dynamic and effective learning environment that encourages active participation and critical thinking (Onowugbeda et al., 2024).

A notable research gap exists in the application of the CTCA framework within the context of secondary education in Lagos. Although constructivist approaches have been extensively studied and implemented in various educational settings worldwide, their specific impact on biology education in Lagos remains underexplored (Ajayi et al., 2023; Leiber, 2022). This gap underscores the necessity for empirical research to investigate how the CTCA framework can be adapted to address the unique challenges and opportunities in Lagos schools. By addressing this gap, the research can offer valuable insights into the effectiveness of CTCA in enhancing student learning outcomes, thereby informing future educational practices and policies.

Moreover, the emphasis on the nutrient cycle as the focal topic is particularly relevant given its importance in the broader context of biology and its practical applications. Understanding the nutrient cycle is essential for addressing global challenges such as waste management (Nitrogen cycle), addressing climate change (Carbon cycle), improving water quality (Water cycle) and supporting sustainable agriculture (Nitrogen cycle, water cycle and carbon cycle). 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 believe that CTCA will enhance the achievement of biology students, particularly in Nutrient cycling in nature.

Research questions

1. Is there any difference in the achievement of students taught Nutrient Cycling in Nature using the Culturo-Techno Contextual Approach (CTCA) and the lecture method?
2. What are the opinions of biology students regarding the effectiveness of the Culturo-Techno-Contextual Approach (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 Nutrient Cycling in Nature 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 Nutrient Cycling in Nature).

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 Nutrient cycling 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 nutrient is cycled in nature, they can better understand how plants absorb nutrients like Nitrogen which is a macro nutrient for plants.

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 Nutrient Cycling in Nature, these pre-lesson activities not only stimulate relevant prior knowledge but also offer students a wider perspective that deepens their comprehension. Exploring different viewpoints—such as cultural practices or digital resources—enriches their cognitive frameworks and builds 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.

Together, these theories investigate the integration of three key elements: culture, technology, and context, to improve academic performance in the teaching and learning of biology. By incorporating Vygotsky's sociocultural theory and Ausubel's theory of meaningful learning, the study explores how the Culturo-Techno-Contextual Approach (CTCA) utilizes social interactions, cultural insights, and technological tools to foster an engaging and effective 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.

METHOD

Design

This research employed an explanatory sequential mixed-method design, integrating both quantitative and qualitative approaches to gain a thorough understanding of the study's objectives. The mixed-method approach was particularly suitable for this study as it enabled the combination of numerical data with rich, contextual insights from participants. In the quantitative phase, a two-group pretest-posttest non-equivalent quasi-experimental design was utilized. This phase included two intact classes: an experimental group (exposed to the CTCA method) and a control group (taught using the traditional lecture method). Intact classes were chosen to maintain the natural classroom environment, reduce ethical and administrative challenges, and ensure the practicality of implementing the intervention within the existing school structure. Both groups were initially assessed using the Nutrient Cycling Achievement Test (NCAT) to measure their baseline understanding of plant nutrition. The experimental group then underwent the CTCA intervention, while the control group continued with conventional lecture-based teaching. After the intervention, both groups were retested using the NCAT to measure changes in their performance. In the qualitative phase, data were gathered using the Students Biology Interview Protocol (SBIP). This phase aimed to capture students' perspectives and experiences with the CTCA teaching approach, providing deeper insights into the quantitative findings and offering a detailed analysis of the effectiveness of CTCA in improving the learning of nutrient cycling in nature.

Context and Participants Details

The population for this study included all senior secondary school biology students in Lagos State, located in the southwestern region of Nigeria. At the time of the study, Lagos State was divided into six educational districts (Districts I–VI) for administrative and quality control purposes. Junior and senior secondary schools in Lagos are categorized into these districts based on geographical locations. Education District V, which was randomly selected for this study, comprises sixty-six senior secondary schools. All districts share similar characteristics, such as teacher qualifications, training support, and quality control under the same regulatory body, making District V a suitable choice. Additionally, Education District V is divided into rural and urban areas, aligning with the study's focus on deep-rooted cultural knowledge. Two public senior secondary schools from District V were randomly selected using a simple ballot system, with one school from a rural area and the other from an urban area.

The selection of these two schools was guided by practical and methodological considerations. The schools were chosen from intact classes to maintain the natural classroom environment and minimize disruptions to regular academic activities, as school policies prohibited the randomization of students. The geographical separation between the rural and urban schools was intentional to prevent inter-group interaction, which could introduce biases or extraneous variables that might affect the study's outcomes. Using intact classes not only adhered to institutional norms but also enhanced the ecological validity of the study, ensuring that the findings were applicable to real-world classroom settings. This approach was also logistically efficient, saving time and resources that would have been required to create new randomized groups. Moreover, it preserved the existing group dynamics and learning progress of the students, aligning with ethical considerations aimed at minimizing any negative impact on their education. By utilizing intact classes that reflect typical classroom environments in Lagos State, the study ensured that its findings were relevant and applicable to the context in which they were intended to be implemented.

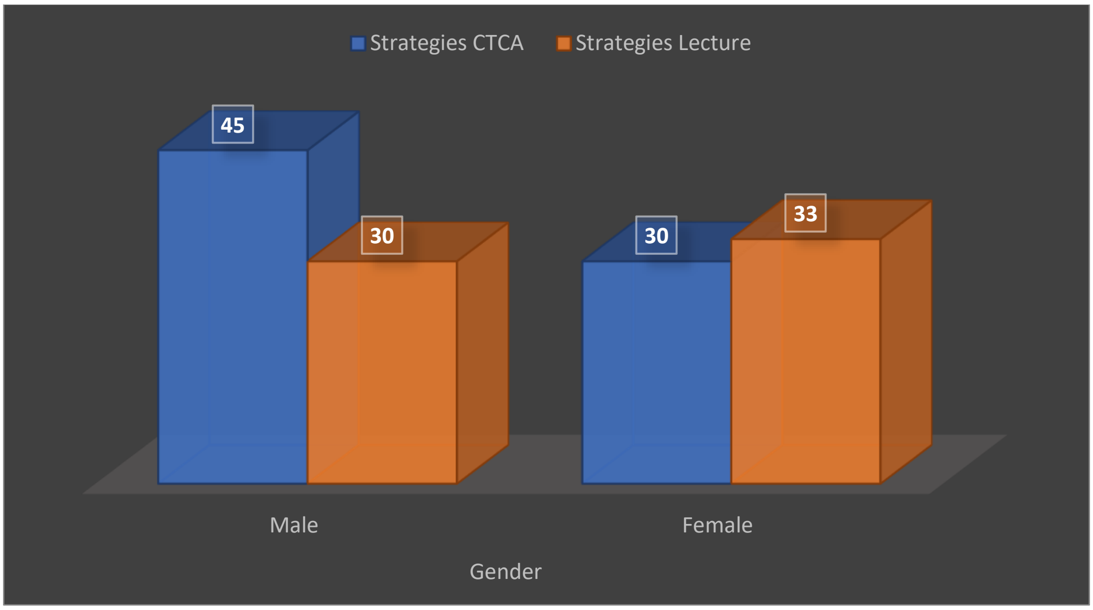

Figure 3: Shows the distribution of students (male and female) in the groups

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 were 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 Nutrient Cycling Achievement Test (NCAT) and the Students Biology Interview Protocol (SBIP). The NCAT 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 school location. Section B contained 30 multiple-choice questions on nutrient cycling in nature. Initially, the test consisted of 50 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 NCAT 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. The 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 SBIP, 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 SBIP, 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 SBIP with a small group of students who shared similar characteristics with the main study sample just as in the case of NCAT, 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. The aim of this pre-test was 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 a period of 3 weeks. The experimental group received 4 weeks of instruction using the Culturo Techno Contextual Teaching 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 one 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 Biology Interview Protocol (SBIP) was used during these interviews to collect qualitative data about the students' views on the CTCA approach, particularly on how it influenced their achievement in Nutrient cycling. The interviews were structured around key questions, such as:

- *Share your thoughts on the Culturo-Techno-Contextual Approach (CTCA) used to teach plant nutrition in your class.*
- *How effective do you find the CTCA in improving your performance in biology, and what challenges have you faced with this method?*

These interviews offered meaningful qualitative perspectives on how students viewed the influence of the Culturo-Techno-Contextual Approach (CTCA) on their experience in learning.

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 Nutrient Cycling in Nature. During the study period, the experimental cohort received three hours of weekly instruction in plant nutrition. The teacher, having achieved a high level of proficiency in the CTCA, 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.

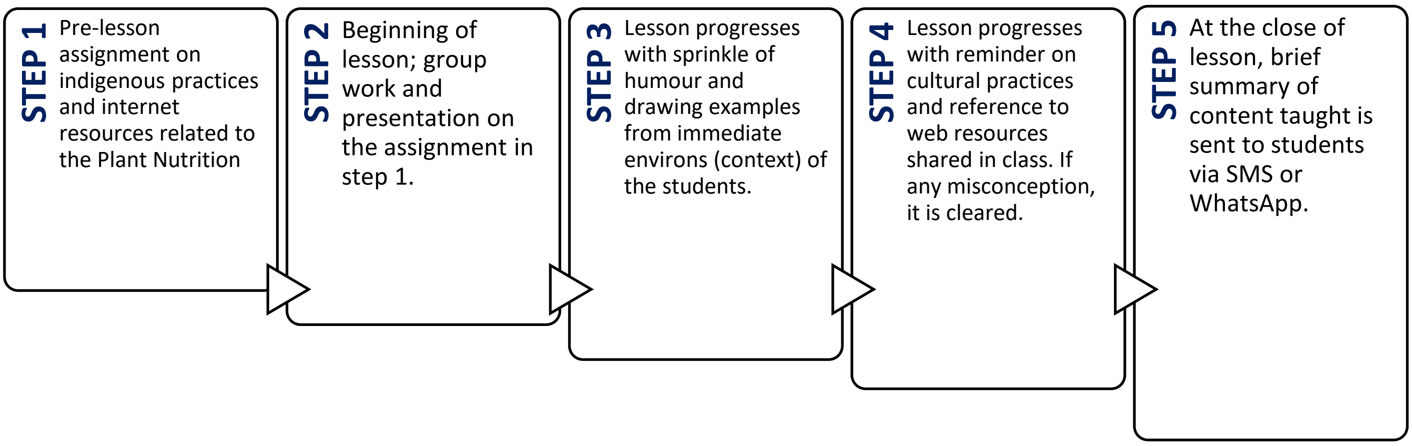

Figure 4: The stages involved in the implementation of CTCA in the classroom (Source: Gbeleyi et al., 2022)

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, nutrient cycling in nature, and requested that they (a) reflect on indigenous knowledge or cultural practices and beliefs associated with the topic or concept (nutrient cycling in nature). 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 nutrient cycling in nature was to explain that the Yoruba man believes once his communities worship rivers (e.g., Osun, Ogun, Yemoja), it reinforces the importance of maintaining clean water sources. This is the "context" flavours 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 nutrient cycling in nature.

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 water cycling.

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 nutrient cycling in nature in the South-West which was used to teach the concept of nutrient cycling in nature:

NITROGEN CYCLE

Fermentation of Locust Beans ("Iru"): The microbial breakdown of locust beans into a protein-rich food product reflects indigenous knowledge of microbial action in nitrogen cycling. This is used to explain the importance of Nitrosomonas in breaking ammonium compound to nitrite

Figure 5: Image of IRU (Locust bean) (source: IyaLoja direct)

Rain as a Natural Fertilizer: Farmers understand that rainwater improves soil fertility. Unknowingly, they observe how lightning and rainfall contribute to nitrogen fixation, replenishing nitrogen compounds in the soil. This concept direct fixation of nitrogen to the soil by electrical discharge.

Figure 6: Image of Rain Splash (Premium Times magazine 2023)

Carbon Cycle

Agroforestry and Tree Planting: Traditional practices involve planting trees like Iroko (Milicia excelsa) and Baobab (Adansonia digitata) alongside crops to maintain soil fertility and store carbon. The Yoruba people have long practised agroforestry, integrating trees with crops and livestock to maintain ecological balance and enhance carbon storage in vegetation and soil. This was used to explain how carbon is removed from the atmosphere.

Figure 7: Image of tree planting (Source NBC 2024)

Water Cycle

Rain-making Ceremonies and Invocations: Traditional priests (Babalawos) and rainmakers perform rituals and sacrifices to invoke rain. This is used to explain the importance of precipitation in water cycle.

Figure 8: Image of a Herbalist invoking rain (Source: Duru 2024)

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 nutrient cycling in nature, but without incorporating CTCA. The teaching process involved a four-step approach:

Step1: The teacher introduced the topic of nutrient cycling in nature to the students.

Step2: The concept of nutrient cycling in nature (nitrogen, water and carbon) was explained in detail.

Step3: Students were allowed to ask questions at the end of the lesson.

Step 4: The teacher summarized the lesson and assigned homework.

Data Analysis

We utilized mean and standard deviation to interpret the research question, while Analysis of Covariance (ANCOVA) was chosen as the most appropriate statistical method for our study. This decision was based on the study's focus on a single dependent variable (achievement) and the inability to randomly assign participants to either the CTCA or lecture group. ANCOVA was conducted, with pre-test scores included as a covariate to account for initial differences between the groups. For the qualitative data, an interpretive thematic analysis approach was employed, enabling a detailed discussion of the in-depth interviews. The audio recordings of the interviews were replayed multiple times, and verbatim transcriptions were created. These transcripts were meticulously reviewed several times to identify emerging themes relevant to the interpretation and reporting of the study's key findings.

RESULTS

Our major quest for this study was to investigate if CTCA enriches the achievement of students in Nutrient cycling in nature. 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 any difference in the achievement of students taught Nutrient Cycling in Nature using the Culturo-Techno Contextual Approach (CTCA) and the lecture method?

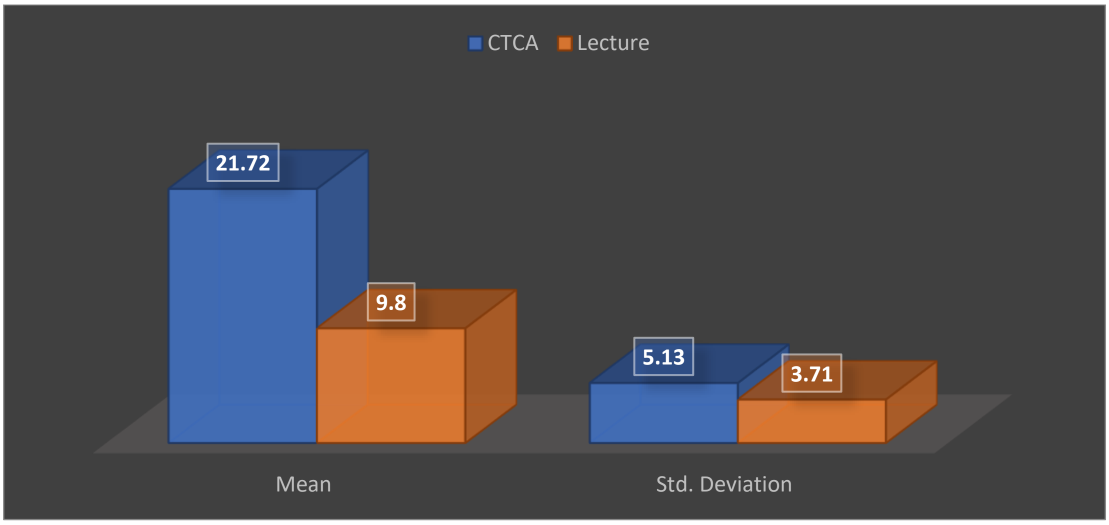

Figure 9: Mean and standard deviation of students in the CTCA group and Lecture group.

The descriptive statistics showed that the experimental group achieved a higher mean score (21.72) than the control group (9.80). Additionally, the experimental group had a greater standard deviation (5.13) compared to the control group (3.71).

To assess whether this difference was statistically significant and not just a result of random variation, we performed additional inferential statistical analyses. The outcomes of these tests are detailed in Table 2.

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

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)						

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 nutrient cycling in nature 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 enhance the credibility of the findings and ensure they were not solely based on quantitative data, students' perspectives on the Culturo-Techno-Contextual Approach (CTCA) were gathered through in-depth interviews. Excerpts from these interviews are provided in Table 2 below:

Table 2: Excerpt from interviews done to the students'

Theme	Summary of Finding
Views of students about CTCA and its impact on achievement.	"The method has been very helpful to me. My performance in biology has improved because of the teaching approach used, and I no longer have to rely on cramming" (Student 1, male). "The class was engaging because it was interactive. It moved quickly, but incorporating our cultural elements made it more relatable" (Student 2, female). "This method encourages me to think critically and explain concepts better. It motivates me to study more, and I find it very interesting" (Student 3, female). "The way we discussed in class and connected the lessons to everyday objects made understanding plant nutrition easier, even with some funny and unusual examples (laughs)" (Student 4, female). "For me, sir, I no longer struggle to remember things. I now have clear references to remind me of what we've learned. Please bring more indigenous objects to class to help us perform even better" (Student 5, male). "I'm really pleased with this method. It helped me understand the lessons better and appreciate them more" (Student 6, male).

Table 2 indicates that the Culturo-Techno-Contextual Approach (CTCA) was largely well-received by the students. A substantial 80% of the students shared positive feedback about the method, affirming that it significantly improved their understanding of plant nutrition as delivered by their teacher. However, a few students recommended the inclusion of tangible, indigenous materials to further clarify specific concepts related to nutrient cycling in nature.

DISCUSSION

This study primarily aimed to determine if CTCA could improve student achievement in nutrient cycling in nature. The results showed a significant advantage for students taught with CTCA compared to those taught with the lecture method. As one student commented, *"The class was engaging because it was interactive. It moved quickly, but incorporating our cultural elements made it more relatable"* (Student 2, female), suggesting that the approach encouraged them to think critically and engage more deeply with the subject matter. This highlights that the culturally relevant and technology-integrated nature of the Culturo-Techno-Contextual Approach (CTCA) is more effective in teaching concepts related to plant nutrition. These findings align with prior research by Ige et al. (2025), Abdulhadi et al. (2023), Ademola et al. (2023), Akintoye et al. (2023), Awaah et al. (2023), Onowugbeda et al. (2023), Allename et al. (2023), Oladejo et al. (2023b), and Gbeleyi et al. (2022), which demonstrated that CTCA is an effective strategy for improving student achievement in biology and other science subjects.

We propose that students taught using the Culturo-Techno-Contextual Approach (CTCA) outperformed those in the control group because the culturally relevant content enabled them to draw on familiar cultural knowledge and practices related to nutrient cycling in nature. As one student noted, *"The way we discussed in class and connected the lessons to everyday objects made understanding plant nutrition easier, even with some funny and unusual examples (laughs)"* (Student 4, female). Another added, *I'm really pleased with this method. It helped me understand the lessons better and appreciate them more"* (Student 6, male), indicating this his approach's incorporation of cultural and contextual knowledge made the learning experience more engaging and relatable. By connecting the teaching of nutrient cycling to students' diverse cultural backgrounds and real-life experiences, they were able to engage more meaningfully with the subject. This cultural alignment deepened their understanding and offered a unique advantage in comprehending and applying key concepts.

The learners' contextual experiences significantly contributed to the experimental group (CTCA) outperforming the control group (Lecture Method). One student explained, *"For me, sir, I no longer struggle to remember things. I now have clear references to remind me of what we've learned. Please bring more indigenous objects to class to help us perform even better"* (Student 5, male). This indicates that using real-world, culturally relevant examples helped students retain and connect with the information more effectively. The cultural knowledge incorporated in the CTCA group was largely drawn from familiar, everyday experiences within their environment. For example, students who presented at the rain-making ceremony had observed this ritual annually in their community. This familiarity likely deepened their understanding, as they could easily link the significance of rain—a key element in their cultural practice—to its scientific role in photosynthesis. By aligning cultural context with scientific concepts, the approach created a relatable and engaging learning experience, strengthening their comprehension of the subject.

Group work also infuse an element of accountability. As one student shared, *"This method encourages me to think critically and explain concepts better. It motivates me to study more, and I find it very interesting"* (Student 3, female), highlighting that the collaborative nature of CTCA fostered active student participation by instilling a sense of responsibility for their group's success, often resulting in greater commitment and higher engagement levels. The collaborative nature of group activities created a more dynamic and less formal classroom environment, allowing students to interact freely and with confidence. This increased participation contributed to the experimental group's improved performance compared to the control group.

Additionally, Ausubel's theory of meaningful learning builds on Vygotsky's perspective by highlighting the significance of linking new information to existing cognitive frameworks. Ausubel argued that rote learning, where information is memorized without connecting it to prior knowledge, is less effective and less enduring than meaningful learning. In the CTCA classroom, the use of advanced organizers, such as pre-activity assignments provided to students before lessons and concept maps, helped students bridge their prior knowledge with new concepts related to plant nutrition. These organizers offered a cognitive structure that allowed learners to assimilate new information more effectively while avoiding cognitive overload. By explicitly connecting new ideas to existing mental frameworks, the CTCA approach facilitated a deeper and more lasting understanding of plant nutrition, ensuring that learning was not superficial but thoroughly integrated into the students' cognitive systems. This combination of social interaction within the Zone of Proximal Development (ZPD) and meaningful learning through advanced organizers created a powerful synergy, contributing to the observed effectiveness of CTCA in promoting equitable and impactful learning outcomes.

The Culturo-Techno-Contextual Approach (CTCA) significantly enhances cognitive processes and greatly boosts classroom engagement. By strategically assigning pre-class tasks that encourage students to explore diverse cultural perspectives at home and then organizing them into collaborative groups during class, the CTCA creates a rich, multifaceted learning experience. This approach allows students to share varied viewpoints, fostering critical thinking as they analyze topics from multiple angles. Unlike the traditional lecture method, which often excludes learners from the organization of the learning process, the CTCA actively involves students by encouraging them to share their insights and participate in meaningful discussions. Additionally, the collaborative group work promoted by the CTCA facilitates deeper learning through peer interactions, knowledge exchange, and the collective construction of understanding. These well-designed strategies work together to transform the classroom into a dynamic and interactive environment, shifting from passive learning to an active and engaging experience. This heightened engagement and cognitive stimulation lead to improved student performance, as evidenced by the statistically significant improvements shown in the ANCOVA results, which provide strong empirical support for the effectiveness of the CTCA.

Educational Implications

The significant positive impact of the Culturo-Techno-Contextual Approach (CTCA) on student achievement highlights that integrating cultural, technological, and contextual elements into teaching can significantly improve learning outcomes. By connecting content to students' cultural backgrounds, the material becomes more relatable and memorable, enriching their overall learning experience.

CTCA also effectively stimulates cognitive processes. By assigning pre-class tasks that encourage students to explore cultural perspectives, the approach activates prior knowledge, which enhances comprehension and retention of new information. Engaging with diverse cultural viewpoints fosters critical thinking and analysis, promoting deeper understanding.

Additionally, CTCA boosts classroom engagement through group activities. Collaborative learning allows students to work together, share ideas, and learn from one another. This approach encourages active participation, keeping students focused and involved. The social interactions within groups also increase motivation and interest in the subject, creating a more dynamic and interactive learning environment.

CONCLUSION

The significant positive impact of the Culturo-Techno-Contextual Approach (CTCA) on student achievement highlights that integrating cultural, technological, and contextual elements into teaching can significantly improve learning outcomes. By connecting content to students' cultural backgrounds, the material becomes more relatable and memorable, enriching their overall learning experience.

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Ethical Consideration

Prior to the commencement of the study, we secured approval from the relevant educational authorities, including the African Centre for Innovative and Transformative STEM Education and the principals of the participating schools, to carry out the research on their premises. We also obtained written consent from all participants, who signed consent forms to confirm their voluntary involvement. The objectives of the study were clearly communicated to the participants, and we assured them that their responses would remain confidential and used exclusively for research purposes. Both school officials and participants were informed that participation was entirely voluntary and that they could withdraw from the study at any time without providing a reason. Throughout the research process, we ensured that no participant experienced any form of harm or exploitation.

Limitations and Future Directions

Although this study has limitations, such as the relatively small sample size and the focus on a specific subject area, which may limit the generalizability of the findings, we believe that applying this approach in other classrooms with similar subject characteristics could significantly enhance learning outcomes in biology. Additionally, this study offers important implications for both research and practice. For researchers, we suggest further exploration of the Culturo-Techno-Contextual Approach (CTCA) in biology education, extending beyond the topic of nutrient cycling in nature, and involving larger sample sizes and longer study periods. For STEM educators and practitioners, this study highlights the need to reconsider teaching methods and embrace strategies that incorporate the cultural and contextual backgrounds of learners into the teaching and learning process.

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