Asian Journal of Assessment in Teaching and Learning
*Vol 15, Issue 1, 2025 (16-35) /eISSN **2821-2916***

A Tripartite Instructional Approach for Demarginalising Biology Classrooms: Impact on Cognitive Achievement and Process Skills

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Received: 18 Apr 2025; **Revised:** 10 May 2025;
Accepted: 14 May 2025; **Published:** 02 June 2025

To link to this article: https://doi.org/10.37134/ajatel.vol15.1.2.2025

Abstract

Biology classrooms in Nigeria, especially in under-resourced and culturally diverse settings, are often marginalised due to a persistent disconnect between theoretical knowledge in biology and its practical application. This marginalisation stems from rigid teaching methodologies, limited resources, and a lack of contextual relevance, which hinder meaningful learning. The Culturo-Techno Contextual Approach (CTCA) 2.0 offers a tripartite instructional framework to address these 21st-century challenges, particularly in Africa, hence this study examined the impact of the CTCA2.0 on biology students' cognitive achievement and process skills acquisition and further investigated the relationship between the two variables. The study sample consisted of 104 students (science = 38, non-science = 66) from two senior secondary schools in Lagos State South-West, Nigeria. Using an explanatory sequential design, quantitative data were collected through the Biology Cognitive Achievement Test (BCAT) and Biology Process Skills Acquisition Test (BPSAT), with reliability coefficients of 0.79 and 0.76, respectively. Qualitative data were obtained using the Biology Students Interview Protocol (BSIP). Data were analysed using mean, SD, ANCOVA formula and Pearson's correlation. The findings revealed statistically significant differences in cognitive achievement [F (1, 48) = .000; P < .05], process skills acquisition [F (1, 48) = .000; P < .05], and a positive relationship between the two variables (r = 0.24; p =.01) in the experimental group. Despite limitations, the study concluded that CTCA2.0 plays a pivotal role in demarginalising biology classrooms by enhancing students' cognitive abilities and process skills. Therefore, it was recommended that the approach should be adopted to improve students' cognitive ability and process skills in challenging biology concepts.

Keywords: *Assessment, Biology, Cognitive Achievement, Culture-Techno Contextual Approach (CTCA) 2.0, Digestive System, Process Skills*

INTRODUCTION

Science education in Nigeria has experienced significant progress since its formal integration into the curriculum in 1842, with a comprehensive national policy emerging in 2018 to strengthen science and technology education (Olofin et al., 2023). Despite these efforts, the sector still grapples with systemic issues such as overcrowded classrooms, inadequate funding, and a shortage of qualified teachers (Ogunode et al., 2022; Jacob & Josiah, 2021; Ihebom & Uko, 2020). These challenges contribute to poor learning environments and a growing disconnect between theoretical knowledge and practical skills, especially in fields like technology and entrepreneurship (Ncanywa, 2023). While the Nigerian government acknowledges the transformative potential of science education in promoting innovation, critical thinking, and economic development, the inconsistent implementation of innovative strategies, particularly in under-resourced areas hinders progress (Ogunode et al., 2022; Jacob & Josiah, 2021). To address this, there is a growing emphasis on hands-on, practical learning to ensure students develop essential life and professional skills.

In the context of biology education, although the curriculum aims to build a strong scientific foundation, students often struggle to connect abstract concepts with real-world applications, leading to a persistent knowledge-skills gap (Oludipe et al., 2022). This issue is exacerbated by the dominance of exam-oriented, rote memorization teaching styles and the limited incorporation of culturally relevant, indigenous knowledge (Onyewuchi & Owolabi, 2022; Ezeanya-Esiobu, 2019). The continued use of Western teaching models without contextual adaptation has led to inconsistent academic performance, as shown in WAEC reports (WAEC, 2016–2024; Adams et al., 2023). Contributing factors include poor lab facilities, oversized classes, undertrained teachers, and socio-economic constraints. Furthermore, students face barriers related to language, home environment, and a lack of awareness about biology's real-life relevance. These challenges underscore the urgent need for a more context-sensitive educational approach that integrates indigenous knowledge with modern pedagogies, aiming to create inclusive, practical, and effective science learning environments (Okebukola et al., 2016; Knaus et al., 2022; Awaah et al., 2022; Wabuke, 2016).

1. Cognitive Achievement, Process Skills and Science Learning

In the realm of education, particularly science learning, cognitive achievement and process skills work in tandem to promote meaningful understanding and application of knowledge. Using Bloom’s Taxonomy as a framework, cognitive achievement encompasses stages from basic knowledge acquisition to higher-order skills such as analysis, synthesis, and evaluation, essential for developing critical thinking and problem-solving abilities in disciplines like biology (Prabha & Dhanalakshmi, 2022; Onochojare et al., 2018). Unlike general academic performance, cognitive achievement specifically measures intellectual development, mastery of scientific concepts, and preparedness for specialized careers. However, its development is often hindered by poor instructional materials, overloaded curricula, and insufficient laboratory practice (Mugabe & Ndayambaje et al., 2021; Okebukola, 2020). Addressing these challenges requires a more hands-on, contextually grounded approach that connects theoretical instruction with real-world relevance.

Science process skills serve as essential tools for students to explore and interpret their environment, supporting the transformation of abstract concepts into practical understanding (Azhar & Megahati, 2022; Wabuke, 2016). These skills are categorized into basic (e.g., observing, classifying, measuring) and integrated types (e.g., experimenting, modeling, interpreting data), and are critical for inquiry-based learning and scientific reasoning in biology. Skills such as creating models and defining operationally help simplify complex biological ideas and foster analytical thinking (Akintoye et al., 2024; Akinbobola & Bada, 2022; Oludipe, Saibu, & Owolabi, 2022). At the core of effective science education are critical thinking and problem-solving, competencies that depend on strong cognitive abilities and process skills (see Figure 1). In today's rapidly evolving knowledge economy, nurturing these competencies is crucial. As emphasized by Nwachukwu (2024), Rushiana et al. (2023) and Benea-Popuşoi & Duca (2022), 21st-century education must prioritize not just test-based knowledge but also the development of creativity, collaboration, communication, and digital literacy. Teaching methods in biology must thus shift from rote memorization to active engagement that enables students to apply learning independently or collaboratively in solving real-world problems (see Figure 1).

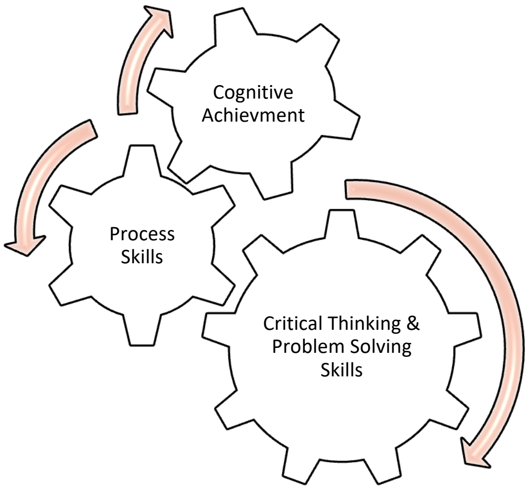

Figure 1 The interrelatedness of cognitive achievement and science core skills

2. Overview and Evolution: From CTCA to CTCA2.0

In response to the limitations of Eurocentric teaching models, the Culturo-Techno-Contextual Approach (CTCA), an Afrocentric and tripartite pedagogy, was developed to address classroom challenges in African contexts by integrating indigenous knowledge, technology, and contextual learning (Adam et al., 2024). Rooted in over four decades of research, CTCA emphasizes cultural relevance by linking academic content to students' lived experiences, traditions, and local environments, making learning more engaging and meaningful (Okebukola, 2020). It follows a five-step process that includes pre-lesson preparation, group reflection on cultural practices and web-based resources, contextual examples, clarification of cultural misconceptions, and lesson summaries shared via SMS or WhatsApp (Okebukola, 2016). This approach fosters collaboration, technological engagement, and cultural grounding, aligning with social constructivism (Vygotsky, 1962), advance organizers theory (Ausubel, 1963), and Kwame Nkrumah's ethnophilosophy. Empirical studies have validated CTCA's effectiveness in enhancing students' understanding of complex STEM subjects across African classrooms through teaching, lab work, and field experiences (Awaah et al., 2022; Abdulhadi et al., 2022).

The transformation of CTCA to the enhanced Culturo-Techno Contextual Approach (CTCA) 2.0 is like the growth of a seed into a flourishing tree. While CTCA laid the foundational roots by effectively bridging students' cultural knowledge with scientific concepts, CTCA2.0 represents a more mature, robust version that has grown to better address the complexities of modern science education. Just as a tree develops stronger branches and deeper roots over time, CTCA2.0 retains the core components of its predecessor (see Figure 2) but with significant improvements, upgrading its capacity to cater to diverse learning environments and overcome previous limitations. This metamorphosis strengthens its ability to foster deeper, more meaningful learning experiences, much like how a tree expands its canopy to provide more shade and nourishment to the ecosystem around it. The updated version stands as a testament to the evolution of educational approaches, enhancing its reach and impact in classrooms across Africa and beyond.

The Culturo-Techno Contextual Approach (CTCA) 2.0 builds on the foundational principles of the original CTCA by incorporating key upgrades to enhance its effectiveness in modern educational settings. While both versions emphasize culture, technology, and context, CTCA2.0 introduces the expanded use of digital resources, including cultural web platforms and the Afrocyberlibrary, to ensure equitable access to indigenous knowledge (see Figure 3). It enriches lesson delivery through the strategic integration of indigenous metaphors and analogies, making scientific concepts more relatable and accessible. Unlike the original model, CTCA2.0 includes formal assessment tools such as quizzes to provide real-time feedback (see Figure 3), and shifts toward a more student-centered approach that promotes active participation and critical thinking. Additionally, it allows for longer, more detailed lesson summaries beyond the original 320-character limit and supports diverse technological platforms (e.g., SMS, WhatsApp, Telegram) for flexible lesson delivery (see Figure 3), creating a more inclusive and personalized learning experience (see Figure 2).

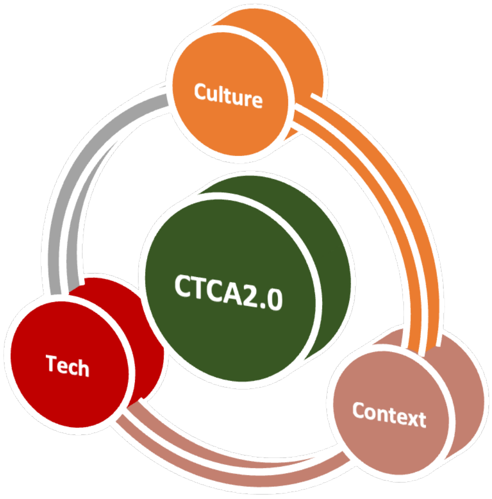

Figure 2 The CTCA2.0 components

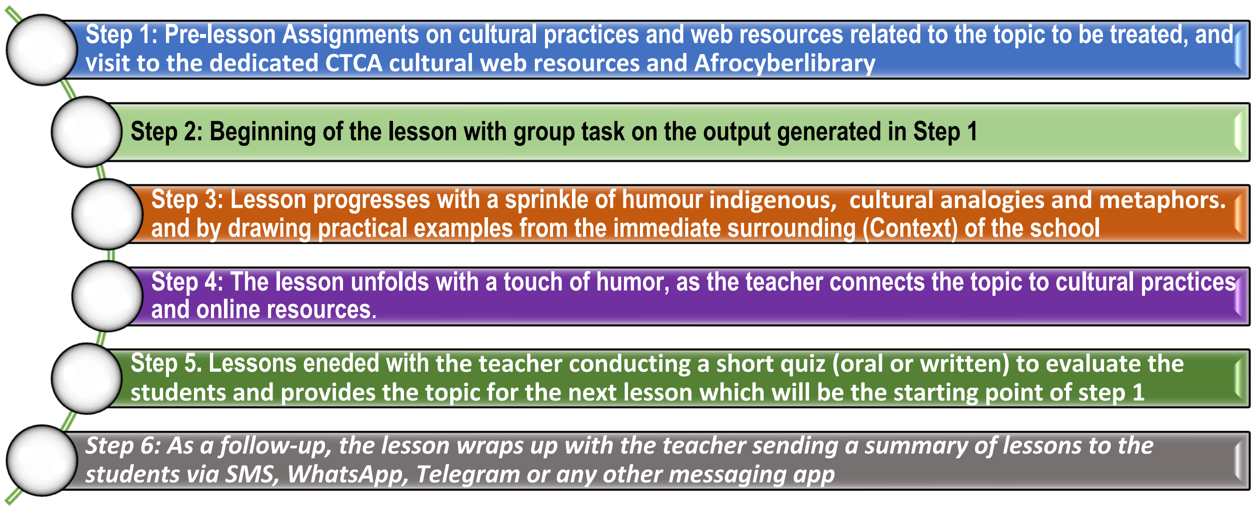

Figure 3 Steps in implementing CTCA2.0

This study contributes to the field by shifting focus from short-term academic achievement to the development of cognitive abilities and process skills in biology education, employing the enhanced CTCA2.0, which integrates culture, technology, and locational context to promote meaningful learning. This study stands out as the first to explore how CTCA2.0 enhances cognitive growth and promotes the acquisition of science process skills which are essential components for lifelong learning and real-world scientific application.

3. Why Digestive System?

Given the scope of this study, digestive system is a pivotal topic in the senior secondary biology curriculum due to its essential role in human health and its relevance to both science and non-science career paths. It teaches students about the structure and function of key organs such as the stomach, intestines, liver, and pancreas, and equips them with knowledge vital for making informed health and dietary choices. For science students, it serves as a foundation for careers in medicine, nursing, dietetics, and biotechnology, while enhancing scientific literacy and critical thinking skills through inquiry-based learning. Non-science students also gain practical health literacy, supporting better decision-making regarding nutrition and well-being (Oktaviana et al., 2023). Despite its importance, the digestive system is widely regarded as one of the most difficult topics in biology, as reflected in a study by Okebukola et al. (2020) and WAEC Chief Examiners' reports (WAEC, 2016; WAEC, 2019; WAEC, 2024), which cite consistently low student performance. Addressing this learning gap, the present study proposes the use of CTCA2.0 to enhance cognitive ability and process skills in biology, making this research both timely and crucial for STEM education. Three research questions were formulated to guide the study:

1. Is there any difference in the cognitive achievement of science and non-science students taught digestive system using the CTCA2.0?
2. Is there any difference in process skills acquisition of science and non-science students taught digestive system using the CTCA2.0?
3. Is there any relationship between the cognitive achievement and process skills acquisition of students taught digestive system with CTCA2.0?
4. What are the views of students on the efficacy of CTCA2.0?

4. Theoretical Review

This study is grounded in Okebukola's eco-technocultural theory, Vygotsky's social constructivist theory, and Ausubel's subsumption theory, which together form the theoretical foundation of the CTCA2.0 instructional model. Okebukola's eco-technocultural Theory emphasizes the relevance of connecting classroom learning to students' cultural backgrounds, local environments, and the digital technologies they interact with daily (Awaah et al., 2022; Cen-Yagiz & Aytac, 2021). This is evident in CTCA2.0's implementation steps (see Figure 3), where lessons begin with pre-lesson tasks involving cultural inquiry and online research (Step 1), and continue with the use of local, practical examples and humour to contextualize learning (Step 3). This approach promotes inclusivity and make abstract biology concepts more meaningful to the students. Additionally, Vygotsky's social constructivist theory is reflected in CTCA2.0 through structured group tasks and collaboration (Step 2), where students co-construct knowledge by sharing their individual findings and cultural insights (Adams et al., 2024; Akintoye et al., 2024; Awaah et al., 2022). The teacher serves as a facilitator, guiding students within their zone of proximal development. Meanwhile, Ausubel's subsumption theory supports the model's focus on building connections between new and prior knowledge by using advance materials such as YouTube videos and personal experiences (Step 1), and by structuring lessons to support meaningful retention (Step 5). The use of messaging platforms like WhatsApp and Telegram to send lesson summaries (Step 6) further demonstrates the integration of technology in reinforcing learning outside the classroom, in line with Eco-Technocultural Theory. Together, these theories underpin the CTCA2.0 framework, creating a learning environment that is socially interactive, contextually grounded, and cognitively structured.

METHODS

We employed an explanatory sequential design, a mixed-method approach consisting of a quantitative phase followed by a qualitative phase. The quantitative phase used a quasi-experimental design with intact classroom groups to align with the school structure and avoid disruptions from reorganization. The qualitative phase involved in-depth interviews to provide deeper insights into the quantitative results. Multi-stage sampling was employed to select participants, at first, education district one was randomly chosen from the six districts in Lagos State, South-West Nigeria. Next, two public senior secondary schools were randomly selected from the chosen district, as the schools shared similar characteristics such as teacher qualifications and centralized administration. The study involved 104 Senior Secondary School II (SS II) students, comprising 46 males and 58 females, with an average age of 14 years. These students were divided into two groups: 51 students (science = 20, non-science = 31) in the Culturo-Techno Contextual Approach (CTCA) 2.0 group and 53 students (science = 18, non-science = 35) in the lecture method group. About 68% of the total students were from the Yoruba ethnic group, and all participants were proficient in English, ensuring effective communication. Intact classes were used to minimize confounding variables and maintain validity. SS II students were selected for their foundational knowledge of nutrition and food classes, which served as prerequisites for the digestive system topic, and for their availability during a stable learning period before standardized exam preparations. The digestive system was chosen for its relevance to food security, health education, and career pathways, as well as its perceived difficulty. This was supported by reports from WAEC chief examiners (2016, 2019, 2020, and 2024) and surveys on challenging biology topics (Okebukola, 2020). Additionally, the integration of cultural and indigenous knowledge into teaching this topic remains underexplored. The participants in this study (experimental and control) groups were exposed to pretest, treatment, posttest and then the interview (experimental only).

Quantitative data were collected using firstly the Biology Cognitive Achievement Test (BCAT). BCAT assessed the students' cognitive proficiency in digestive system, has 30 discrete multiple-choice questions self-developed in line with the standard of West African examination council (WAEC) and recommended biology textbooks. The questions contained four options lettered A−D, each item had three distractors and one key. The instrument adapted the Bloom's taxonomy to ensure a balanced evaluation across various cognitive domains with each item carrying an equal score weight of one point. A sample of the multiple-choice question includes;

- Which structure prevents food from entering the trachea during swallowing?
- Which of the following nutrients begins its digestion in the mouth?

Secondly, we employed Biology Process Skills Acquisition Test (BPSAT), a self-developed instrument to assess students' mastery of biology process skills. Similar to the BCAT, the BPSAT was created based on recommended biology textbooks and the West African Examination Council (WAEC). Additionally, BPSAT consists of two sections: Section A collects demographic details, including students' gender and age, while Section B features 30 multiple-choice questions focused on digestive system. Each question includes one correct option and three distractors. A test blueprint (Wabuke, 2016) was used to ensure the questions provided a balanced assessment of 12 process skills considered in this study: observing, classifying, measuring, communicating, inferring, predicting, interpreting data, controlling variables, defining operationally, hypothesizing, experimenting, and creating models. All questions carried equal weight, with one point assigned per correct answer. Examples of BPSAT questions include:

- How would you create a timeline map that illustrates the journey of corn through the digestive system from ingestion to egestion?
- What do you predict would happen if the stomach was bypassed during the digestion of corn?

To ensure a comprehensive validation of the instruments, we engaged three experts; one biology teacher and two science education lecturers (biology major), these are experts in the field for over a decade of teaching experience and expertise in coordinating and marking WASSCE. They rigorously reviewed the questions and answer options for clarity, relevance, and alignment with the intended cognitive abilities, ensuring a clear correct answer and plausible distractors. They verified that each item matched the WASSCE curriculum and lesson objectives. Two science teachers assessed the items' structure for consistency with the lesson plans. Following their feedback, the original 38 items were refined to 30, with four rephrased for clarity, ensuring the instrument's validity and suitability for its purpose. Items identified as difficult to interpret were refined for clarity, ensuring that the instrument could accurately assess students' knowledge.

After the instruments (BCAT & BPSAT) were carefully reviewed by experts in science education, we moved forward with a pilot test with 30 students outside our samples. This step was essential to see how the questions would perform in the main study. To ensure that the items on each test were consistently measuring the same thing, we used Cronbach's alpha, a statistical method that helps us understand whether the items on the instrument are in sync with each other. To do this, we entered the scores from the pilot test into SPSS (version 23). This test essentially measures how well the items on a test "hang together." For the BCAT, the Cronbach's alpha came out to 0.79, and for the BPSAT, it was 0.76. These numbers fall comfortably within the accepted range of 0.70 to 0.80, which tells us that the instruments are reliably measuring what they are supposed to measure. In simple terms, the questions are aligned, and students' answers showed a clear pattern. Since both the BCAT and BPSAT hit that mark, we felt confident that they would give us consistent results in the main study.

1. Treatment

The study unfolded in a well-structured sequence designed to ensure clarity and minimize bias. Initially, pretests were administered to both the experimental and control groups to measure the students' baseline achievement and process skills levels. The BCAT was given first, followed by the BPSAT after a 10-minute break, to prevent test fatigue. These pretests were conducted in the morning, between 9:10 a.m. and 10:50 a.m., to optimize students' focus and avoid encroaching on the school's break period. Each test lasted 45 minutes, with one minute and thirty seconds allotted per question. This process aimed to establish that any observed effects were not influenced by prior knowledge. The teaching and learning phase began the day after the pretests and lasted for five weeks. Both the experimental and comparison groups received equal contact time, with lessons conducted for 80 minutes each week. To mitigate teaching bias, the regular classroom teachers were engaged for instruction in their respective groups. Before the intervention, the teacher assigned to the experimental group underwent rigorous training to implement the Culturo-Techno Contextual Approach (CTCA). This included three micro-teaching sessions to ensure good mastering of the approach. Lessons for the experimental group were subsequently delivered using the CTCA approach, emphasizing active participation and integrating cultural, technology contexts. In contrast, the control group was taught using the lecture method.

2. Lesson delivery in the CTCA2.0 classroom (Experimental Group)

Teachers' Instructional Guide on Culturo-Techno Contextual Approach 2.0 (TIGCTCA2.0) was adopted here to teach digestive system in the experimental group. The six steps involved are as follow:

a. Step 1. Pre-lesson tasks on cultural practices and online resources about the digestive system

The pre-lesson tasks helped students explore and understand the diversity of cultural practices while engaging with reliable online resources. First, they were encouraged to use their phones, tablets, or computers to search for information about the digestive system online. This could involve watching educational videos on platforms like YouTube, reading articles, or visiting trustworthy websites that explain how the digestive system works. Second, students were invited to connect with their families or communities to learn about traditional or cultural practices related to food, digestion, or health. They could talk to parents, siblings, or older relatives to gather insights, hear stories, or learn about their culture related digestion. With these tasks, students were able to create a sense of connection and shared learning at home.

b. Step 2: Beginning of the lesson with group task on the output generated in Step 1

The lesson began with group work, focusing on the output from the pre-lesson tasks. This activity aimed to encourage students to collectively analyse and combine their individual findings, promoting interpersonal communication, critical thinking, and unity. Inside the classroom, the teacher introduced the topic and divided the students into mixed-ability and mixed-gender groups, with each group consisting of up to ten students. In their groups, students took turns sharing the findings of their research from the pre-lesson tasks. Each group was assigned a leader responsible for recording and presenting the group's findings (see Figure 4-7). The group discussions lasted for about 12 minutes, after which the leaders reported their discussion in 5 to 8 minutes. The teacher also participated by sharing personal Indigenous knowledge and cultural practices related to digestive system. This exchange of ideas created an inclusive atmosphere which brought about mutual respect and cultural exposure among the students. Some of the indigenous analogies/metaphors and cultural practices used to exemplify related concepts in digestive system are;

- Tapping of Palm wine: The process of saliva secretion in the mouth was explained using the traditional method of extracting juice from palm trees (see Figure 4) commonly refers to as tapping palm wine (in Yoruba called "*Dida emu ope*"). In this practice, the tapper cuts (stimulates) the palm tree and allows the sap to flow out into a collecting container. Similarly, when food enters the mouth, the salivary glands are stimulated to secrete saliva, which moistens and prepares the food for chewing, much like how the sap moistens the collecting process.

Figure 4 Tapping of palm wine exemplifying secretion
Source: https://media.sciencephoto.com/image/c0026576/800wm/C0026576-Palm_wine_production

- Local Grinding Stones: Chewing food in the mouth with the teeth was compared with the grinding of pepper using two stones (see Figure 5), a common practice in many African households. The two stones (grinding stones) called *"Olo ata"* in Yoruba symbolizes the upper and the lower jaws. The repetitive grinding action breaks down the pepper into smaller particles, just as the teeth break down food into smaller pieces to aid digestion.

Figure 5 Local grinding stones describing chewing and grinding in the mouth
Source: https://images.hive.blog/0x0/https://files.peakd.com/file/peakd-hive

c. Step 3: Lesson progresses with a sprinkle of humour and by drawing practical examples from the immediate surrounding (Context) of the school

As the lesson moved forward, the teacher brought the topic to life using familiar, everyday examples from the students' surroundings to explain how the digestive system works. Bits of subject-related humour were added along the way to keep the atmosphere light and engaging. These relatable and practical examples (see Figure 6) made the science easier to understand and more enjoyable to learn.

This part of the lesson known as the contextual phase of CTCA, which aimed to help students connect with the topic in a way that felt real, boosting both their interest and memory of what they learned.

- African Children Sliding in the Mud during the Rainy: The movement of food down the oesophagus through peristalsis can be likened to children sliding down a muddy slope during the rainy season (see Figure 6). The mud reduces friction, allowing the children to slide smoothly, just as the rhythmic contraction and relaxation of muscles in the oesophagus propel food down to the stomach.

Figure 6 African children sliding in the mud during the rainy season explaining peristalsis in the oesophagus
Source: https://encryptedntbn0.gstatic.com/images

- Indigenous *Ways of Fermenting Cassava in Africa:* Garri (Cassava powder), which is a home-made products in Africa is known to be processed from cassava (*"ege"* in yoruba) through several strenuous processes. During this process, the peeled cassavas are grinded and left to ferment before draining the cassava to reduce the starch contents. The absorption of water and formation of faeces in the large intestine can be likened to the traditional process of fermenting cassava (see Figure 7). In this practice, water is gradually drained from the cassava, leaving behind a solid residue. Similarly, the large intestine absorbs water from undigested food, compacting it into feces for egestion.

Figure 7 Indigenous ways of fermenting cassava in Africa used to explain absorption
Source: https://encryptednthjhgffbn0.cassava fermenation/images

d. Step 4: The lesson unfolds with a touch of humor, as the teacher connects the topic to cultural practices and online resources.

As the class continued, the teacher highlighted the significance of the indigenous analogies, metaphors and cultural practices submitted during the lessons. Misconceptions related to the indigenous and cultural practices were addressed by the teacher. At this juncture, the use of humour and the teacher's connection of the lesson to cultural traditions and online resources aimed to establish a lively and interactive classroom atmosphere. This approach augmented students' knowledge of the subject and illuminated the practical relevance of students culture in the process of learning biology and stimulated thoughtful reflection and hands-on engagement.

e. Step 5: Closing activities, quiz and introduction to the next topic

At closure, the teacher asked some questions, allowed the students to discuss in groups while their cognitive abilities and the process skills exhibited were observed. Samples of the questions given to the students are stated below:

1. How would you present the role of different organs in corn digestion to your classmates?
2. What do you predict would happen if the stomach was bypassed during the digestion of corn?

These activities gave immediate feedback and helped the teacher identify areas that needed further clarification. Following the evaluation, the teacher introduced the next lesson topic. This served as a foundation for the next step (step 1) as discussed earlier in this study.

f. Step 6: The lesson wraps up with the teacher sending a summary of lessons to the students via WhatsApp or Telegram.

After each class, a brief lesson summary was sent to the students via Telegram and WhatsApp to the students. Initially, the teacher sent the first summary, but afterward, student's group leaders took over this task.

3. Lesson delivery in the lecture method classroom (Control Group)

In the control group, students were taught the digestive system using the Teachers' Instructional Guide on the Lecture Method (TIGLM), a traditional, teacher-centered approach common in Nigerian classrooms. The lesson followed a rigid structure where the teacher reviewed the previous topic, introduced new concepts through verbal explanations, and wrote key points on the chalkboard for students to copy. The focus was on delivering factual content with minimal student engagement, emphasizing passive learning over interaction or critical thinking. Unlike the CTCA2.0 method (see Figure 3), this approach did not encourage connections to students' cultural experiences, indigenous knowledge, or the use of online resources. Lessons concluded with a summary and homework assignment, offering little room for collaboration or deeper understanding.

To validate our findings, we allowed the same biology teachers to teach the experimental and control groups, minimizing bias from teacher-related factors. Posttests (BCAT for cognitive achievement and BPSAT for process skills) were administered the day after the intervention to assess immediate learning impacts, with reshuffled pretest questions to prevent memorization. The student numbers were kept consistent across both groups for fair comparison, and teachers clarified that the tests wouldn't impact grades, reducing stress and allowing students to perform naturally. This approach helped ensure accurate and authentic data.

4. Conduct of Interviews

Going beyond the test scores, we conducted semi-structured interviews with ten students (five boys and five girls) from the experimental group who had shown regular attendance and active participation. Held the day after the posttests in a quiet classroom setting, the interviews created a relaxed atmosphere where students felt comfortable sharing their honest thoughts. Each 12-minute session, conducted between 9:20 a.m. and 10:30 a.m., encouraged students to reflect on their experiences with the CTCA2.0 teaching method, especially its impact on their understanding of digestive system and development of process skills. Using the Biology Students Interview Protocol (BSIP), open-ended questions invited students to express what worked, what challenges they faced, and how the lessons could be improved. Responses were recorded, with permission and key non-verbal cues like gestures and expressions were noted to enrich interpretation. The interviews were transcribed and analyzed thematically, revealing meaningful insights into how CTCA2.0 shaped students' learning experiences and provided a personal, qualitative layer to support the quantitative results.

RESULT AND DISCUSSION

The research questions were addressed using Mean and Standard Deviation, while the null hypotheses were tested using Analysis of Covariance (ANCOVA) and Pearson's Product Moment Correlation (PPMC). ANCOVA was selected due to the non-random assignment of students to groups, and PPMC was used to assess the relationship between two continuous dependent variables. Analyses began with tests for parametric assumptions to ensure the suitability of the chosen inferential methods. Data were analyzed using IBM SPSS version 23, with hypotheses tested at a 0.05 significance level. Qualitative data from interviews were examined using an interpretative thematic approach, with repeated review of audio recordings and verbatim transcriptions to identify key themes. Preliminary tests showed that the Shapiro-Wilk test confirmed normal distribution for both the experimental group (N = 51), [F = .45; p > .05] and the control group (N = 53), [F = .63; p > .05], as reported by Tim (2024). Levene's test for homogeneity of variance also indicated no significant variance difference between the groups [F = .029; p > .05], meeting the assumption of equal variances.

To answer research question one which sought to investigate the difference in cognitive achievement of science and non-science students when taught digestive system concepts with CTCA2.0. The pretest and posttest score were subjected to descriptive statistics of mean and standard deviation. The results in Table 1 shows that the science and non-science students in the CTCA2.0 group had a comparable Mean Diff. of 9.00 and 8.40 with SD Diff. of 2.60 and 2.40. This implies that CTCA2.0 enhanced the cognitive ability of both science and non-science students. However, to ascertain whether this observed comparable difference is real or attributed to error variance, this result was further checked with one-way ANCOVA.

Table 1 Mean and standard deviation of difference in cognitive achievement scores of sciences and non-science students in the experimental group

Group	N	Mean		Mean diff	SD		SD Diff
		Posttest	Pretest		Post-test	Pre-test	
Science	21	23.50	14.50	9.00	5.80	3.20	2.60
Non-Science	30	21.30	12.90	8.40	6.10	3.70	2.40

Results in Table 2 depicts a statistically significant difference [F (1, 48) = 0.01; *P* < .05]. This result further explains that CTCA2.0 had no influence of the process skills of science and non-science students. Also, the partial eta squared estimate indicated that the treatment accounted for 37% of the variance observed in the cognitive ability of students in digestive system.

Table 2 ANCOVA summary table of difference in cognitive achievement of science and non-science students in the experimental group

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Pn^2
Corrected Model	4.142[a]	2	2.07	0.07	0.92	0.37
Intercept	1435.15	1	1435.15	53.96	0.00	0.51
Pretest	3.502	1	3.50	0.13	0.21	0.00
Discipline	0.348	1	0.34	0.01	0.00	0.00
Error	1329.66	48	26.59			
Total	31241.00	51				

R^2= 0.370 (Adjusted R^2 = -0.037) *Significant at p<0.05

The research question two examined the difference in process skills acquisition of science and non-science students taught digestive system with CTCA2.0, The results in Table 3 indicates that the science and non-science students in the CTCA2.0 group showed a comparable Mean and SD differences with science students having 5.70 and 1.10 while their counterparts in the non-science class had 3.60 and 1.20 respectively. This implies that CTCA2.0 enhanced the process skills of both science and non-science students.

However, to ascertain whether this observed comparable difference is real or attributed to error variance, this result was further subjected to the inferential statistics of ANCOVA. From the results in Table 4, the initial difference in process skills (pretest) between the science and non-science students was significant [F (1, 48) = 0.34; $p > 0.05$], but after the treatment, a non-statistically significant difference was observed [F (1, 48) = 0.000; $P < 0.05$]. Also, the partial eta squared estimate indicated that the treatment accounted for 44% of the variance observed in the process skills of students in digestive system.

Table 3 Mean and standard deviation of difference in process skills acquisition scores of sciences and non-science students in the experimental group

Group	N	Mean		Mean diff	SD		SD Diff
		Posttest	Pretest		Posttest	Pretest	
Science	20	27.50	21.80	5.70	3.50	2.40	1.10
Non-Science	31	23.40	19.80	3.60	3.80	2.60	1.20

Table 4 ANCOVA summary table of difference in the process skills acquisition scores of sciences and non-science students in the experimental group

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Pn²
Corrected Model	65.69[a]	2	32.84	1.10	.34	.44
Intercept	1087.71	1	1087.71	36.56	.00	.43
Pretest	27.84	1	27.85	.94	.33	.02
GROUP	40.68	1	40.69	1.38	.00	.03
Error	1428.22	48	29.76			
Total	39706.00	51				

R^2 = 0.440 (Adjusted R^2 = 0.004) *Not Significant at $p<.05$

The third research question examined the relationship between cognitive achievement and process skills acquisition of students taught digestive system using the CTCA2.0. The results in Table 5 revealed students performed moderately well in cognitive ability and process skills tests. The two variables had comparable mean and SD difference, the Mean diff for cognitive achievement is 9.24 and 9.30 while their SD diff is 0.21 and 0.20.

Table 5 Mean and Standard Deviation of cognitive achievement and process skills acquisition scores in the experimental group

Variable	N	Mean		Mean diff	SD		SD Diff
		Posttest	Pretest		Posttest	Pretest	
Cognitive Achievement	51	67.45	58.21	9.24	8.12	7.91	0.21
Process Skills Acquisition	51	69.30	60.00	9.30	6.95	6.75	0.20

The results further indicate improved cognitive ability and process skills when taught with CTCA2.0. To determine the direction and significance of the relationship observed in Table 5, the data was further subjected to Pearson's correlation equation. We observed a positive relationship (see Table 6) between students' cognitive ability and process skills acquired after the treatment [r= 0.24; $p = 0.01$]. Given the coefficient value of .24 and the significance level of .01, it implies that an improved performance in students' cognitive ability when taught digestive system with CTCA2.0 enhanced their process skills.

Table 7 depicts that most participants (6 students) shared positive feedback about CTCA2.0, noting that the approach was interesting, promoted active students' participation, enhanced their understanding of digestive system, and made the class more interactive, effectively eliminated boredom. These findings are evident in the following statements, this implies that the approach has enhanced their cognitive achievement in biology. Similarly, the process skills of students were enhancing as most of the responses agreed that they develop a variety of process skills when taught with CTCA2.0. They affirmed that the approach was effective in enhancing their process skills, specifically in observing, classifying, communicating and inferring skills. Meanwhile, few students (40%) reported that certain skills, such as measuring, controlling variables, defining operationally were more challenging to acquire through the approach.

Table 6 Pearson correlation of cognitive achievement and process skills acquisition scores in the experimental group

		Cognitive Achievement	**Process Skills Acquisition**
Cognitive Achievement	Pearson Correlation	1	0.24**
	Sig. (1-tailed)		0.01
	N	51	51
Process Skills Acquisition	Pearson Correlation	0.24**	1
	Sig. (1-tailed)	0.01	
	N	51	51

**. Correlation is significant at the 0.01 level (1-tailed)

Table 7 Findings from the interviews (excerpt)

Theme	**Summary of Finding**
Theme I: Impact of CTCA2.0 on science and non-science students' cognitive achievement	*"It really helpful to me, my improve due performance in biology will to the teaching method that was used and I don't have to cram again (Student 1 Male, 15years, Science class);* *The class was interesting because the class was interactive, yes, it is really fast" (Student 4, Female, 15years, non-science class);* *"The method makes me think and explain things better...it encourages me more to read, I think it is interesting " (Student 2, Female, 16 years – non-science class);* *"With how we chatted in the class and relate our teaching to things around us, I understand better" (Student 7 Male, 16years, non-science class):*
Theme 2: Impact of CTCA2.0 on science and non-science students' process skills	*"I acquired skills like observing and classifying, but measuring was tough without tools" (Student 4 Female, 15yesars, Science class);* *"In fact the method helped my Communicating and observing skills, but operational definition is was difficult "(Student 10 (Male, 16years, non-science class);* *The method of teaching made it easy for me to classify and observe, but modeling needs more materials"(Student 5 Female, 17years, Science class);*

The research question one explored the difference in cognitive achievement between science and non-science students taught digestive system using CTCA2.0. Results showed no statistically significant difference between the two groups (see Table 4), indicating that the approach was equally effective for both science and non-science students. This was supported by qualitative feedback from the students, who described the method as being helpful to understand digestive system. One student noted, *"It really helped me, my performance in biology improved due to the teaching method used, and I don't have to cram anymore"* (Student 1, Male, 15, Science class), while another added, *"The class was interesting because it was interactive and really fast"* (Student 4, Female, 15, Non-science class) (see Table 7). These findings align with Sholanke (2020), Adam (2019), and Oludotun (2021), who also found CTCA to be effective across different student backgrounds. Although science students may have had a slight advantage due to prior exposure, both groups benefited from CTCA2.0's culturally grounded and collaborative learning environment, consistent with Onowugbeda et al. (2022). Recent studies reinforce CTCA's impact on students' academic achievement. Akintoye et al. (2023) noted that students performed better in STEM subjects under CTCA, while Adam et al. (2024) and Onowugbeda et al. (2024) observed greater retention and performance in complex biology topics. Olusegun et al. (2024) also confirmed these results in senior secondary chemistry classes. Despite these positive outcomes, implementation challenges remain. Ifeanacho (2023) reported students' concerns about the time demands of CTCA, and Oladejo et al. (2024) noted the lack of significant gender-based performance differences, suggesting further research is needed. Resource limitations and insufficient cultural integration in some schools (Oladejo et al., 2024; Onowugbeda et al., 2024) also pose hurdles. To improve the method's success, scholars like Adam et al. (2024), Ifeanacho (2023), and Olusegun et al. (2024) recommend teacher training and context-specific adaptation. As digital tools evolve, future research should examine how mobile apps and interactive platforms can support and expand CTCA's impact.

Research question two sought the difference in the process skills acquisition of science and non-science students taught digestive system using the CTCA2.0. The results showed no significant difference between the two groups as both science and non-science students (80% of participants) reported that CTCA2.0 helped them develop process skills, such as observing, classifying, communicating, and inferring during the qualitative phase of this study. However, they found certain skills, like measuring, controlling variables, and defining operationally, more challenging to acquire. A science student mentioned, *"I acquired skills like observing and classifying, but measuring was tough without tools,"* while another non-science student shared, *"The method helped my communicating and observing skills, but operational definition was difficult."* These findings align with Gbeleyi (2021), who found that CTCA improves critical thinking skills, closely related to process skills in biology, and Darmaji et al. (2022), who highlighted the link between process skills and critical thinking. Additionally, studies have shown that CTCA promotes equitable learning opportunities and enhances critical thinking and process skills for both male and female students (Akintoye et al., 2024). The integration of technology in CTCA further supports the development of process skills, with Nganyadi (2024) noting the positive impact of Computer-Assisted Instruction on students' performance in biology. Although no significant difference was found between science and non-science students. The findings agree with Okebukola eco-technocultural theory which emphasizes the role of the learning environment and cultural experiences in learning, while Vygotsky's social constructivist theory highlights the importance of cultural knowledge and social interaction, the Ausubel's subsumption theory supports the acquisition of process skills by linking new information to students' existing knowledge. The overall effectiveness of CTCA2.0 in promoting process skills suggests it is a valuable pedagogical tool for teaching science to the non-science students.

The third research question investigated the relationship between cognitive achievement and process skills acquisition in students taught the digestive system using the CTCA2.0 framework, revealing a positive correlation. Students who performed better cognitively also demonstrated greater proficiency in process skills, supported by qualitative insights from student interviews. For example, one student noted, *"My performance in biology has improved because I no longer need to cram; the interactive nature of the class makes it faster and easier to learn"* (Student 1, Male, 15 years, Science class). Other students reported gaining skills such as observing and classifying, though some faced challenges, such as difficulty in measuring without tools (Student 4, Female, 15 years, Science class). The findings align with previous studies by Ebere and Appolonia (2017), Sukarno and Hamidah (2013), and Rabacal (2016), which highlighted the positive impact of culturally relevant, hands-on teaching methods on academic achievement and process skills. Recent studies by Akintoye et al. (2023) and Adam et al. (2024) also support these findings, emphasizing CTCA's ability to improve academic performance and knowledge retention, with students outperforming their counterparts in biology and STEM subjects. Despite these positive outcomes, challenges in implementing CTCA were noted in some studies. Ifeanacho (2023) raised concerns about the time required for CTCA implementation, while Oladejo et al. (2024) found no significant gender-based performance differences in the experimental group, suggesting that CTCA's impact might not be universally experienced. Furthermore, Okereke et al. (2024) observed no achievement differences between male and female students, though context-based methods like CTCA proved effective in improving student performance. Challenges in resource availability and the integration of cultural contexts were also mentioned (Oladejo et al., 2024; Onowugbeda et al., 2024). These challenges highlight the need for improved teacher training and more equitable access to resources to optimize the implementation of CTCA. The study's findings align with three theoretical frameworks that suppot CTCA2.0: Okebukola's eco-technocultural theory shows how cultural analogies help students connect biological concepts to real-life experiences, improving comprehension, similarly, the Vygotsky's social constructivist theory emphasizes the role of social interaction, with peer collaboration and teacher guidance boosting both cognitive and process skills and the Ausubel's subsumption theory suggests that linking new content to prior knowledge enhances understanding, which CTCA2.0 achieves through cultural relevance. These theories collectively explain how CTCA2.0's integration of indigenous analogies and metaphors, cultural practices and technology leads to improved student performance.

IMPLICATION ON INSTRUCTIONAL ASSESSMENT

The Culturo-Techno Contextual Approach (CTCA) 2.0 represents a paradigm shift in biology education, especially in under-resourced regions like Africa. This study underscores the significant positive impact of CTCA2.0 on both cognitive achievement and process skills acquisition. To harness the potential of this innovative instructional approach, it is crucial to reflect on its implications for instructional assessment. Rethinking traditional assessment methods and embracing a contextually relevant framework can ensure a more inclusive and assessment of students' cognitive achievement, process skills acquisition, socio-cultural influences.

The notable improvement in cognitive achievement among students taught using CTCA2.0 suggests the need to re-evaluate traditional assessment methods. Standardized tests, which often emphasize rote memorization and theoretical knowledge, may not fully capture students' understanding and application of biological concepts. Therefore, assessments should be designed to evaluate critical thinking, problem-solving abilities, and the capacity to apply knowledge in real-world contexts. Project-based assessments, open-ended questions, and practical examinations are effective methods to achieve this goal. Project-based assessments allow students to engage in long-term projects, applying the knowledge of biological concepts to solve real-life problems. Open-ended questions encourage students to explain their reasoning and thought processes, while practical examinations assess students' ability to perform experiments, collect and analyze data, and draw conclusions based on their observations.

The study indicates a significant enhancement in students' process skills acquisition through CTCA2.0. Process skills, such as observation, experimentation, and data interpretation, are fundamental for scientific inquiry and should be a key focus of instructional assessment. Traditional paper-and-pencil tests often fall short in assessing these skills. Instead, performance-based assessments, portfolios, and peer and self-assessment should be incorporated. Performance-based assessments involve observing and evaluating students as they engage in scientific investigations and experiments in biology. Portfolios allow students to compile a collection of their work, including laboratory reports, research projects, and reflective journals, demonstrating their development of process skills over time. Peer and self-assessment encourage students to evaluate their own and their peers' performance, this will enhance scientific process and promote critical thinking.

CONCLUSION

This study highlights the need to demarginalize biology classrooms through the CTCA2.0 framework, which combines cultural relevance, technology, real world context, and the use of Indigenous analogies and metaphors to create a more inclusive and meaningful learning experience. By connecting biological concepts to students' everyday lives and cultural backgrounds, especially through Indigenous knowledge and practices, CTCA2.0 makes science more relatable and engaging. It supports the development of both cognitive and practical skills, helping to close the performance gap between science and non-science students. This approach also encourages critical thinking, problem solving, and equitable access to biology education, ensuring that all students feel valued, supported, and capable of succeeding in science. Within the limitations of the study, we recommend the following:

i. Widespread adoption of CTCA2.0 in secondary schools through the revision of the biology curriculum to integrate cultural relevance, practical applications, and Indigenous knowledge, building on the foundations of CTCA1.0.
ii. Significant investment in teacher training and capacity building through regular professional development on CTCA2.0 and culturally responsive teaching methods to ensure effective classroom practice.
iii. Enhancement of learning environments by promoting the use of technology, encouraging hands-on activities, and supporting Indigenous project-based exhibitions and science fairs to foster interactive and applied science learning.

However, the study faced several limitations that may have influenced the results. The use of intact classes limited randomization, affecting the generalizability of findings. Irregular student attendance reduced the sample size, impacting the reliability of the analysis. Limited access to internet-enabled devices hindered individualized learning and reduced the effectiveness of CTCA2.0 for some students. Future research should address these issues by improving resource availability, increasing sample size, and exploring long-term impacts.

ACKNOWLEDGEMENT

The authors would like to thank the Africa Centre of Excellence for Innovative and Transformative STEM Education (ACEITSE) - a World Bank funded project at the Lagos State University, Ojo, Lagos State, Nigeria, for providing the support and facilities. This work was initiated and conceptualized by A. O. and O. O. H. A. handled the data curation, while the formal analysis was conducted by A. O. and U. A. S. L. and O. A. undertook the investigation, with U. A. developing the methodology. Necessary resources were acquired thanks to T. A.'s efforts, and the project was supervised by O. O. The original draft was written by A. O., with review and editing carried out by U. A. The team would also like to acknowledge the contribution of various individuals whose assistance and support were invaluable throughout the study. We extend our heartfelt gratitude to all the students who participated in this study and entrusted us with their perspectives. Our sincere appreciation also goes to the school authorities and students who took part in this research, particularly the chemistry teachers who provided invaluable support during the administration of the treatment. We extend special thanks to those who have been instrumental in providing guidance and support, ensuring the project's success. Additionally, anyone named in the acknowledgments section has consented to being so included.

FUNDING

The APC was funded by the Africa Centre of Excellence for Innovative and Transformative STEM Education (ACEITSE) – a World Bank funded project at the Lagos State University, Ojo, Lagos State, Nigeria.

DATA AVAILABILITY STATEMENT

Data generated and analysed for this study are available upon request from the corresponding author.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest and affirm that there are no competing financial interests among them.

REFERENCES

Acarli, D. S., & Dervişoğlu, S. (2021). Effect of inquiry-based biology laboratory applications on scientific process skills, attitude, self-efficacy and self-confidence. *MIER Journal of Educational Studies Trends and Practices*, *11*(1),15-29. DOI: https://doi.org/10.52634/mier/2021/v11/i1/1751

Adam, U. (2019). Potency of culturo-techno-contextual approach on students' achievement in and attitude towards mutation and variation. *[Unpublished research project report]. Lagos State University*. https://www.academia.edu/download/84815869

Adam, U. A. (2023, August 8). Unleashing the power of culture, technology, and context: A study on the efficacy of Culturo-Techno-Contextual Approach on students' knowledge retention. *Science Teachers Association of Nigeria [Conference Presentation], 63 STAN Conference Proceedings, Lagos, Nigeria https://d1wqtxts1xzle7.cloudfront.net/105696316/2023_*

Adam, U. A., Adeyemi, A. D., Lameed, S. N., Gafar, M. A., & Joy, A. T. (2024). Decolonizing biology classrooms in Nigeria: The significance of Culturo-Techno-Contextual Approach. *Erudio Journal of Educational Innovation, 11*(2), 173-186. https://erudio.ub.ac.id/index.php/erudio/article/view/671

Adam, U. A., Lameed, S. N., Owolabi, T., Onowugbeda, F. U., Oladejo, A. I., Okebukola, P. A., & Mustapha, G. A. (2024). The potency of culture, technology, and context in a biology classroom: Culturo-Techno-Contextual Approach in action. *International Journal of Science Education, 47* (1), 1-26. https://www.tandfonline.com/doi/abs/10.1080/09500693.2024.2405667

Adeosun, G; Oladejo, A. I.; Okebukola, P. A.; Adebayo, I.; Agbanimu, D. O.; Ademola, I.; Onawugbeda, F. I.; Peter, E.; Gbeleyi, O.; Awaah, F. (2022, March 19-22). I am CTCA, and this is my first Attempt in the Physics Class How Will I perform?. [Conference paper]. 95th NARST Conference, Vancouver, British Columbia. https://www.researchgate.net/profile/Adekunle-Oladejo/publication/361503734_I_am_CTCA_and_this_is_my_first_Attempt_in_the_Physics_Class_-_How_Will_I_perform/links/62b5707cd49f803365b5c60f/I-am-CTCA-and-this-is-my-first-Attempt-in-the-Physics-Class-How-Will-I-perform.pdf

Akinbobola, A. O., & Bada, A. A. (2022). The acquisition of science process skills through entrepreneurial physics education in senior secondary schools. *REID (Research and Evaluation in Education)*, *8*(2), 181-192. (DOI) 10.21831/reid.v8i2.48787

Akintoye, H., Adam, U. A., Lameed, S. N., Bankole, I. S., & Ayodeji, B. (2023). A case for culturo-techno-contextual approach for enhanced academic achievement in STEM education. *Journal of Educational Sciences, 7*(4), 530-544. https://doi.org/10.31258/jes.7.4.p.530-544

Anamuah-Mensah, A. (2020). Indigenous Knowledge System and Quality STEM Education [PowerPoint slides]. LASU ACEITSE Lecture on Indigenous Knowledge System and Quality STEM Education; YouTube, April 27. https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.academia.edu/106536961/Conference_Proceedings&ved=2ahUKEwjOmsae8PqMAxViVEEAHTgTA1kQFnoECCAQAQ&usg=AOvVaw3gCKg9TdWRDs45SFEGajye

Nicolaides, A., & Steyn, J. (2023). Towards Authentic African Higher Education based on African Epistemology. *Journal of Education Culture and Society*, *14*(2), 116-128. https://www.ceeol.com/search/article-detail?id=1226694

Apeadido, S., Opoku-Mensah, D., & Mensah, G. O. (2024). Enhancing Process Skills and Academic Performance in Biology: The Impact of Practical Work. *Integrated Science Education Journal*, *5*(1), 34-41. https://doi.org/10.37251/isej.v5i1.854

Ausubel, D. P. (1963). A subsumption theory of meaningful verbal learning and retention. *The Journal of general psychology*, *66*(2), 213-224. https://doi.org/10.1080/00221309.1962.9711837

Azhar, A., & Megahati, R. R. P. (2022). Process Skills through Student Worksheet Based on Around Nature in Materials Temperature and Heat. *Journal of Digital Learning and Distance Education*, *1*(3), 108-113. https://doi.org/10.56778/jdlde.v1i3.25

Benea-Popuşoi & Duca, 2021). The development of human creativity as a way to compete globally and make knowledge economy more inclusive. In *Proceedings of the Fourteenth International Conference on Management Science and Engineering Management: Volume 2* (pp. 676-686). Springer International Publishing. https://doi.org/10.1007/978-3-030-49889-4_52

Darmaji, D., Kurniawan, D. A., Astalini, A., & Rini, E. F. S. (2022). Processing skill and critical thinking: reviewed based on the gender. *JPI (Jurnal Pendidikan Indonesia)*, *11*(1), 133-141. https://doi.org/10.23887/jpi-undiksha.v11i1.35116

Ebere, I., & Appolonia, A. N. (2017). Effects of Ethnoscience and traditional laboratory practical on process skills acquisition of secondary school biology students in Nigeria. *British Journal of Multidisciplinary and Advanced Studies*, *1*(1), 10-21. http://bjmas.org/index.php/bjmas/article/view/4

Ezeanya-Esiobu, C. (2019). *Indigenous knowledge and education in Africa* (p. 115). Springer Nature. http://library.oapen.org/handle/20.500.12657/23270

Awaah, F., Okebukola, P., Shabani, J., Solarin, D., & Emmanuel Okyere, E. (2022). I am a cultural teaching method-I was Successful in the ICT Class in the Global South. *Cogent Education*, *9*(1), 1-15. https://doi.org/10.1080/2331186X.2022.2134704

Gbeleyi, O. A., Okebukola, P. A., Potokri, O., Aribisala, B. S., & Shabani, J (2022). Enhancing Students' Attitude and Gender Equity in Stem Using Culture, Technology, Humour, Context to Logic Gate. *Technology, Humour, Context to Logic Gate*. https://dx.doi.org/10.2139/ssrn.4079286

Ifeanacho, J. O. (2023). Exploring the relative effectiveness of Culturo-Techno-Contextual Approach on secondary school student achievement and retention in nervous system. Available at SSRN 4446779. https://dx.doi.org/10.2139/ssrn.4446779

Ihebom & Uko 2020). Challenges and prospects of secondary education in Nigeria. *International Journal of Scientific Research in Education*, *13*(4), 670-688. https://ijsre.com.ng/assets/vol.%2C-13(4)-bartholomew-ihebom.pdf

Jacob, O. N., & Josiah, H. F. (2021). Nigerian educational system: Problems and way forward. *Central Asian Journal of Social Sciences and History*, *2*(8), 23-33. https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://cajssh.centralasianstudies.org/index.php/CAJSSH/article/view/143&ved=2ahUKEwiG-YTH8vqMAxUBQUEAHWsAHd8QFnoECBYQAQ&usg=AOvVaw0Qh0bYwHYpddZnsLgAgxPg

Knaus et al., (2022). *Decolonising African higher education: Practitioner perspectives from across the continent*. Taylor & Francis. https://books.google.com/books?hl=en&lr=&id=3xRoEAAAQBAJ&oi=fnd&pg=PA1985&dq=Knaus+et+al.,+(2022).

Mohajan, H. K. (2017). Two criteria for good measurements in research: Validity and reliability. *Annals of Spiru Haret University. Economic Series*, *17*(4), 59-82. https://www.ceeol.com/search/article-detail?id=673569

Mugabe, L., & Ndayambaje, I. (2021). The implications of large classes on active learning at University of Rwanda-College of Education. *Rwandan Journal of Education*, *5*(2), 215-227. https://www.ajol.info/index.php/rje/article/view/222402

Ncanywa, T. (2023). Eurocentric, Westernized, or Afrocentric curriculum in one university in the Eastern Cape: An entrepreneurship approach. *International Journal of Research in Business and Social Science*, *12*(10), 113-120. https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://ideas.repec.org/a/rbs/ijbrss/v12y2023i10p113-120.

Nwachukwu, G. O. (2024). Human capital development: A driver for educational improvement in Nigeria. *British journal of education*, *12*(6), 30-39. doi: https://doi.org/10.37745/bje.2013/vol12n63039

Ogunode, N. J., Johnson, A. G., & Olatunde-Aiyedun, T. G. (2022). Education crisis in Nigeria and way forward. In *Kresna Social Science and Humanities Research Proceedings of the International Conference on Sustainable Development: Problems, Analysis and Prospects* (pp. 33-47). https://www.researchgate.net/profile/Tope-Olatunde-Aiyedun/publication/360878108

Okebukola, P. A. (2015). Quality or quantity: Positioning the Nigerian university system for the challenges of science and technology in the new millennium. *A paper presented at the 6th Convocation Lecture of Adekunle Ajasin University, Akungba-Akoko (AAUA), Nigeria*. https://www.researchgate.net/profile/Peter-Okebukola/publication/343207616

Okebukola, P., Ige, K., Oyeyemi, A., Olusesi, O., Owolabi, O., & Okebukola, F. (2016). Exploring the impact of Culturo-Techno-Contextual Approach (CTCA) in tackling under-achievement in difficult concepts in biology. *Proceedings of the Conference of the National Association of Research in Science Teaching (NARST)*, USA: Baltimore. https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.researchgate.net/publication/363258159

Okebukola, P. (2020). Breaking Barriers to Learning: The Culturo Techno-Contextual Approach (CTCA). *Slough, UK and Delhi: Sterling*. https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.emerald.com/insight/content/doi/10.1108/jrit-08-2022-0047/full/pdf

Okereke, I., Ogu, B., Olori, G., & Olori, C. (2024). Promoting students' academic achievement on difficult biology concepts using context-based instructional method: Implication for reducing depression among students. *Jurnal Penelitian dan Pembelajaran IPA, 10*(2), 297-312. https://dx.doi.org/10.30870/jppi.v10i2.28784

Oktaviana, R., Nuraeni, E., & Amprasto, A. (2023). The effectiveness of inquiry lesson-based digestive system materials for training students' science literacy ability. *BIO-INOVED: Jurnal Biologi-Inovasi Pendidikan*, *5*(2), 187-194. https://dx.doi.org/10.20527/bino.v5i2.15911

Oladejo, A. I., Olateju, T. T., Ahove, M. A., & Suwadu, B. (2024). A beautiful garment from old fabrics: The analogy of culturo-techno-contextual approach for meaningful learning in science. *Research in Science & Technological Education, 42*(4)1-24. https://doi.org/10.1080/02635143.2024.2309905

Olofin, S. O., Ogunjobi, A. O., Falemu, F. A., & Akinwumi, I. O. (2023). Science Education as a Tool for Achieving Socio-Economic Development of Nigeria. *International Journal of Development and Economic Sustainability*, *11*(4), 33-44. https://www.researchgate.net/profile/Akinwumi-Omolara/publication/374147764

Oludipe, O. S., Saibu, S. O., & Owolabi, O. L. (2022). Exploring entrepreneurial motivated approach in chemistry classroom: Can students learn better. *International Journal of Innovation, Research and Advance Studies (IJIRAS)*, *9*(10), 5-15. https://www.ijiras.com/2022/Vol_9-Issue_10/paper_2.pdf

Olusegun, B. E., Saibu, S. O., Alaka, M. O., & Olude, A. S. (2024). Revolutionizing students' success: The dynamic impact of Cultural-Techno-Contextual Approach on academic achievement in difficult concepts in senior secondary chemistry. *Ilorin Journal of Education, 44*(1), 222-236. https://ije.unilorinedu.sch.ng/index.php/ije/article/view/124.

Onyewuchi, F. A., & Owolabi, T. (2022). Effect of Indigenous Knowledge Systems Strategy on Secondary School Students' Performance in Physics in Lagos State, Nigeria. *International Journal of Innovative Research and Development*, *11*(1). Doi:10.24940/ijird/2022/v11/i1/JAN22024.

Onowugbeda, F. U., Ajose, O. O., Ige, A. M., Odekye, O. T., Fasinro, K. S., & Agbanimu, D. O. (2024). Laughing and learning: Exploring the impact of humor in enhancing biology learning outcomes. *Ilorin Journal of Education, 44*(1), 105-118. https://ije.unilorinedu.sch.ng/index.php/ije/article/view/114.

Onowugbeda, F. U., Okebukola, P. A., Agbanimu, D. O., Ajayi, O. A., Oladejo, A. I., Awaah, F., ... & Ige, A. M. (2024). Can the culturo-techno-contextual approach (CTCA) promote students' meaningful learning of concepts in variation and evolution?. *Research in Science & Technological Education*, *42*(2), 395-411. https://doi.org/10.1080/02635143.2022.2084060.

Onwuatuegwu, I. N., & Paul-Mgbeafulike, V. S. (2023). African traditional educational framework: Unveiling the wisdom beyond western education. *Nnadiebube Journal of Philosophy*, *6*(2), 48-62. https://www.acjol.org/index.php/NJP/article/view/3675.

Prabha, R., & Dhanalakshmi, K. (2022). Effects of cognitive ability on improving employment skills among post graduate students at the university level. *International journal of health sciences*, *6*(S10), 81-87. https://doi.org/10.53730/ijhs.v6nS10.13328.

Rabacal, J. S. (2016). Test of process skills of biology students towards developing of learning exercises. *Asia Pacific Journal of Multidisciplinary Research*, *4*(4), 9-16.

Rushiana, R. A., Sumarna, O., & Anwar, S. (2023). Efforts to develop students' critical thinking skills in chemistry learning: Systematic literature review. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1425-1435. https://doi.org/10.29303/jppipa.v9i3.2632.

Sholanke, O. O. (2020). Micro-organisms as Difficult Concept: Exploring the Efficacy of the Culturo-Techno-Contextual Approach (CTCA) in Improving Achievement of Secondary School Students. Breaking barriers to learning of science: The CTC Approach. Slough UK: Sterling Press.

Sukarno, S., & Hamidah, I. (2013). The profile of process skill (SPS) student at secondary high school (case study in Jambi). *International Journal of Scientific Engineering and Research (IJSER)*, *1*(1), 79-83. https://www.researchgate.net/profile/Sukarno-Sukarno-3/publication/346124450.

Rushiana, R. A., Sumarna, O., & Anwar, S. (2023). Efforts to develop students' critical thinking skills in chemistry learning: Systematic literature review. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1425-1435. https://jppipa.unram.ac.id/index.php/jppipa/article/view/2632.

Cen-Yagiz, S., & Aytac, B. (2021). An Ecocultural Perspective on Learning Disability: Evaluation of Familial and Cultural Factors and Presentation of an Integrated Model. Intech Open. https://doi.org/10.5772/intechopen.95827

Tim, T. (2024). Shapiro-Wilk Test: Definition, How to Run it in SPSS - Statistics How To. Statistics How To. https://www.statisticshowto.com/shapiro-wilk-test/

Wabuke, J. M. (2016). *Effects of inquiry-based learning on acquisition of process skills and achievement in Biology among secondary school students in Wareng Sub-County, Kenya* (Doctoral Dissertation, University of Eldoret). https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449.

West Africa Examinations Council. (2016). Chief examiners' reports WASSCE 2016: Resume of sciences subject. https://www.waecgh.org/uploads/examinersReport/2016/Science16.pdf

West Africa Examinations Council. (2019). Chief examiners' reports WASSCE 2019: Resume of sciences subject. https://www.waecgh.org/uploads/examinersReport/2019/Science19.pdf

West Africa Examinations Council. (2020). Chief examiners' reports WASSCE 2020: Resume of sciences subject. https://www.waecgh.org/uploads/examinersReport/2020/Science2020.pdf

West Africa Examinations Council. (2024). Chief examiners' reports WASSCE 2024: Resume of sciences subject. https://www.waecgh.org/uploads/examinersReport/2024/Science24.pdf