Towards Reconceptualizing Science Instruction in Africa: A Model for Process Skills Acquisition in Culturally Relevant Biology Classrooms

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ABSTRACT

Science teaching in Nigerian classrooms often relies on methods and textbook content that fail to connect with students' culture and environment. This disconnect has made it difficult for students to develop essential process skills in Biology, creating a gap between classroom instruction and meaningful learning outcomes. To address this gap, the study investigated the potency of Culturo-Techno-Contextual Approach 2.0 (CTCA 2.0) in enhancing process skills acquisition in biology. A non-randomized pre-test, post-test quasi-experimental design with a 2x2 factorial matrix was used, involving 227 senior secondary II students from two randomly selected secondary schools using two intact classes in Education District I, Lagos State, Nigeria. The experimental group (113 students) received CTCA 2.0 instruction, while the control group (114 students) was taught using the conventional lecture method over five weeks. Data collected through the Biology Process Skills Acquisition Test (BPSAT) and Process Skills Observation Checklist (PSOC) [BPSAT = 0.81; PSOC = 0.80] were analyzed with mean, standard deviation and ANCOVA. Findings revealed that CTCA 2.0 significantly improved process skills acquisition compared to the control group [$F(1,224) = 60.05$, $p < .05$], students mostly developed inferring, communicating, observing, and classifying skills. Therefore the study concluded that CTCA 2.0 enhances process skills development in biology and recommended its adoption to promote process skills competence in senior secondary schools in Lagos State, Nigeria.

Keywords: Biology, Culturally Relevant Pedagogy, Culturo-Techno-Contextual Approach 2.0, Digestive System, Process Skills

INTRODUCTION

Science instruction in Africa, has long relied on Eurocentric, decontextualized, teacher-centered pedagogy, which often leaves many secondary school biology students ill-prepared to apply knowledge acquired in the classroom in different context (Okebukola et al., 2016). With Nigeria's formal adoption of the Sustainable Development Goals in 2015, especially SDG 4: Quality Education, there is an effort towards transforming the biology curriculum into a more inclusive and inquiry-driven framework (United Nations, 2015). previous studies emphasize that culturally relevant pedagogy, anchored in local contexts can empower biology students to actively construct knowledge and connect classroom concepts to what happens around them (Adam, et al., 2019; Ige et al., 2025). This reconceptualization positions biology classrooms as environments where students

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can carry out experiments, collaborate with one another, and this aligns the focus of science education with global development goals (Ayeni & On, 2022).

Central to this reconceptualization is how the students acquire process skills in biology. Ozgelen (2012) described process skills as the intellectual and practical techniques through which students investigate phenomena, generate evidence, and build explanations about the phenomena. Process skills are typically categorized into Basic Process Skills (BPS) such as observing, classifying, measuring, communicating, inferring, and predicting and Integrated Process Skills (IPS) such as interpreting data, experimenting, hypothesizing, and creating models (Alelaiwi, 2022; Pakombwele & Tsakeni, 2022). These skills form a continuum: observation informs classification and measurement, which underpin inference and prediction; experimentation validates hypotheses, which can then be represented through models (Wabuke, 2016).

The significance of process skills in biology has been identified by several researchers, for instance, Gonzalez et al. (2024) argued that process skills shift learning from mere regurgitation of facts to active engagement with scientific processes, thereby promoting curiosity, independence, and scientific reasoning. Likewise, Achor et al. (2018) emphasized their role in fostering scientific literacy among biology students. Competence in these skills enables learners to appreciate the meaningfulness of science and its application beyond the classroom (Pakombwele & Tsakeni, 2022; Darmaji et al., 2022). This vision aligns with **SDG 4**, which underscores equipping students with the skills needed to address pressing human challenges such as erosion, deforestation, and the promotion of innovation (United Nations, 2015).

Inspite of the significance, the acquisition of process skills in biology among secondary school students is hindered by several interrelated factors. Musah and Umar (2017) observed that inadequate availability and utilization of biology laboratory facilities significantly limit students’ academic achievement and their ability to practice essential scientific skills. Without functional laboratories, learners are deprived of opportunities to engage in observation, experimentation, and data analysis, which are at the heart of scientific inquiry. In addition to resource constraints, large class sizes pose another challenge. Ruffina et al., (2020) demonstrated that overcrowded classrooms negatively affect students’ performance in biology by reducing concentration and limiting opportunities for inquiry-based learning. When teachers are faced with too many students, individualized guidance becomes nearly impossible, and passive learning often takes the place of active engagement.

The examination-oriented nature of the curriculum further compounds the problem. Reports from the examiners (WAEC, 2024) highlight that biology examinations in the region emphasize rote memorization of facts rather than inquiry-based skills. This exam-centric approach discourages teachers from prioritizing process skills and undermines students’ ability to develop critical thinking and problem-solving competencies. Teacher professional development also plays a crucial role in shaping how process skills are taught. Ogieriakhi (2020) stressed that many biology teachers lack adequate training in inquiry-based pedagogy and often rely on traditional content-transmission methods. Without continuous professional development, teachers struggle to integrate process skills into their lessons effectively, leaving students with limited exposure to scientific reasoning.

Finally, the way biology is traditionally taught contributes significantly to the problem. Marbach-Ad and Rietschel (2016) documented how teacher-centered instruction, dominated by lectures and note-taking, restricts students from engaging in authentic scientific practices. This approach reinforces passive learning and undermines the development of process skills, leaving students ill-prepared to apply the knowledge of biology in either solving problems or creating new ideas. A persistent question among researchers and teachers is how process skills should be taught in secondary schools. To teach these skills in biology effectively, teachers must adopt inquiry-based learning approaches that foster curiosity, experimentation, and problem-solving. This is where the acquisition of process skills becomes essential. However, inquiry learning alone is insufficient if it remains disconnected from students’ environments. Gay (2010) emphasized that culturally responsive teaching is most effective when rooted in students’ experiences.

Previous studies further showed that biology students acquire process skills best when teachers embed them in hands-on activities, contextual examples, and problem-based learning (Ademola et al., 2025; Adam et al., 2024b; Çelik, 2022; Ogundowole et al., 2025a). For instance, photosynthesis can be taught by linking it to cassava leaves in local farms rather than abstract textbook diagrams, while microbial activity can be explored through familiar processes such as the fermentation of pap ("ogi" in Yoruba). Such contextualization not only enhances comprehension but also fosters inquiry and critical thinking. Despite this, process skills remain underdeveloped in many Nigerian biology classrooms due to abstract teaching methods. Teachers often rely on textbook-driven examples detached from students' immediate environment—for example, describing ecological niches using temperate forests rather than local farms, or explaining photosynthesis without linking it to cassava growth in nearby fields. These missed opportunities prevent students from applying inquiry meaningfully in their environment, leaving them as passive recipients of information rather than active investigators (Anakwenze et al., 2024; Oladejo et al., 2025b; Osotsi et al., 2025).

To overcome these limitations, biology instruction should be reconceptualized to emphasize process skills within culturally familiar contexts. Culturally relevant pedagogy provides the framework for this transformation. Gay (2010) argues that by integrating students' cultural backgrounds, indigenous knowledge, and familiar examples, teachers make biology instruction more engaging and empowering. This approach bridges the gap between global scientific knowledge and African cultural richness, ensuring that biology students acquire both process skills and cultural grounding necessary for creativity, innovation, and sustainable development (Okebukola, 2020; Oladejo et al., 2025). For senior secondary school biology students, culturally responsive teaching not only enhances understanding of complex topics but also fosters inquiry, critical thinking, and problem-solving. Embedding such approaches within the curriculum ensures that biology education prepares students for national development goals while equipping them with the skills to thrive in diverse scientific and everyday contexts (Ogundowole et al., 2025b; Ige et al., 2025).

The Culturo-Techno-Contextual Approach 2.0 (CTCA 2.0) represents a reconceptualisation of science pedagogy in African classrooms by embedding cultural values, technological tools, and socio-environmental contexts into instruction (Okebukola, 2020; Ige et al., 2025; Oladejo et al., 2022). In 2024, the CTCA metamorphosed into CTCA 2.0, which incorporated indigenous analogies, metaphors, and culturally grounded modes of evaluation (Ogundowole et al., 2025a; Adam et al., 2025; International Research Group, 2024). This updated version harmonizes culture, technology, and environment, embedding science teaching in indigenous knowledge systems while leveraging modern digital platforms within STEM education across Africa (Olofin, Adeyemi, & Musa, 2023; Onyewuchi & Owolabi, 2022).

The implementation of CTCA 2.0 follows a six-step procedure (Ogundowole et al., 2025a). It begins with pre-lesson reflection, where students connect prior knowledge and cultural beliefs to exploratory tasks using internet-enabled devices. Learners then engage in small-group discussions, sharing indigenous practices and cultural insights in mixed-ability, mixed-gender groups to foster inclusivity and peer learning (Adam et al., 2024b). Teachers build on these exchanges through contextualized teaching, employing metaphors, humor, and storytelling to make content relatable (Gay, 2010; Oladejo et al., 2022). Cultural knowledge is deliberately integrated into explanations, with misconceptions clarified through guided instruction. Assessment and transition activities, such as quizzes and reflections, consolidate learning, while digital platforms like WhatsApp, Telegram, SMS, and Instagram extend instruction beyond the classroom (Ige et al., 2025; Ogundowole et al., 2025b). This structured process ensures that biology students actively participate, collaborate, and apply science concepts in ways that strengthen inquiry, critical thinking, and process skills (Melesse et al., 2025).

Previous studies have consistently demonstrated the effectiveness of CTCA 2.0 in enhancing biology learning outcomes. For example, Ogundowole et al. (2025b) reported that students taught with CTCA 2.0 significantly outperformed peers taught with lecture methods in process skills acquisition. Melesse et al. (2025) corroborated this by showing that integrating context-based instructional approaches with the learning cycle improved ninth-grade science process skills. Similarly, Adam et al. (2024b) found that CTCA improved critical thinking skills among senior secondary biology students, while Ademola et al., (2025) reported significant gains in achievement and problem-solving skills in nuclear chemistry, with no gender differences. Collectively, these studies highlight CTCA 2.0's potency in improving process, critical thinking, and problem-solving skills, making it a transformative pedagogy for science education (Oladejo et al., 2025; Okebukola, 2020). However, most of these studies have focused on general science or specific topics outside biology, leaving limited evidence on its efficacy in enhancing process skills digestive system. Furthermore, while CTCA has been shown to enhance achievement, literature is sparse on its impact across the full continuum of process skills, also the extent to which biology students acquire process skills under CTCA 2.0 remains unclear. These gaps warrant investigation and lead to the following research questions.

i. **Is there any difference in the process skills acquisition mean scores of students taught biology with CTCA 2.0 and those taught with the conventional method?**

ii. **To what extent do students taught with CTCA 2.0 acquire process skills in Biology?**

Theoretical Underpinning

This study was anchored on three theories on how students learn effectively. The **Okebukola's Ecotechnocultural Theory** emphasizes that learning should connect with students' cultural background, environment, and use of technology. Okebukola (2020) explains that when lessons are taught in ways that reflect students' everyday realities, they become more engaging and easier to understand. By recognizing culture, context, and humour as part of the learning process, this theory ensures that biology students see science not as something distant, but as part of their own lives (Oladejo et al., 2025). **Vygotsky's Social Constructivist Theory** shows that students learn best when they interact with peers and teachers, building knowledge together through collaboration and guidance (Vygotsky, 1962; Darmaji et al., 2022). In addition, **Ausubel's Subsumption Theory** adds that new knowledge is most meaningful when connected to what students already know, rather than memorized in isolation (Ausubel, 1962; Ausubel, 2012), these theories explain why CTCA 2.0 focuses on students' active participation, peer collaboration, and linking new ideas to familiar ones. This integrated approach helps biology students develop critical thinking (Adam et al., 2024a).

These theories support the **Culturo-Techno-Contextual Approach 2.0** by centering students' learning experiences on culture, collaboration, and meaningful connections. The Ecotechnocultural Theory ensures that learners engage with science concepts in ways that reflect their cultural background and everyday realities, making lessons more relatable and motivating. Supporting this, Vygotsky's Social Constructivist Theory emphasizes peer interaction and teacher guidance, showing that biology students learn best when they collaborate and build knowledge together. Meanwhile, Ausubel's Subsumption Theory highlights the importance of linking new ideas to what students already know, helping them move beyond memorization to meaningful understanding. Therefore, these theories make CTCA 2.0 a student-centered approach that promotes active participation and could enhance process skills acquisition through connecting cultural context, social collaboration, and meaningful learning.

METHODOLOGY

This study used a pre-test, post-test quasi-experimental design with a 2x2 factorial setup. Two teaching methods were compared: the Culturo-Techno-Contextual Approach (CTCA 2.0) and the traditional lecture method. The research involved 227 Senior Secondary II (SS II) biology students from two schools in Education District I, Lagos State, South-West Nigeria. The schools were chosen because they were similar in teacher qualifications, student population, and quality standards. One school was assigned as the experimental group (CTCA 2.0), while the other served as the control group (lecture method). Each group was an intact class since random assignment was not possible due to school regulations. The experimental group had 113 students, and the control group had 114 (see Figure 1).

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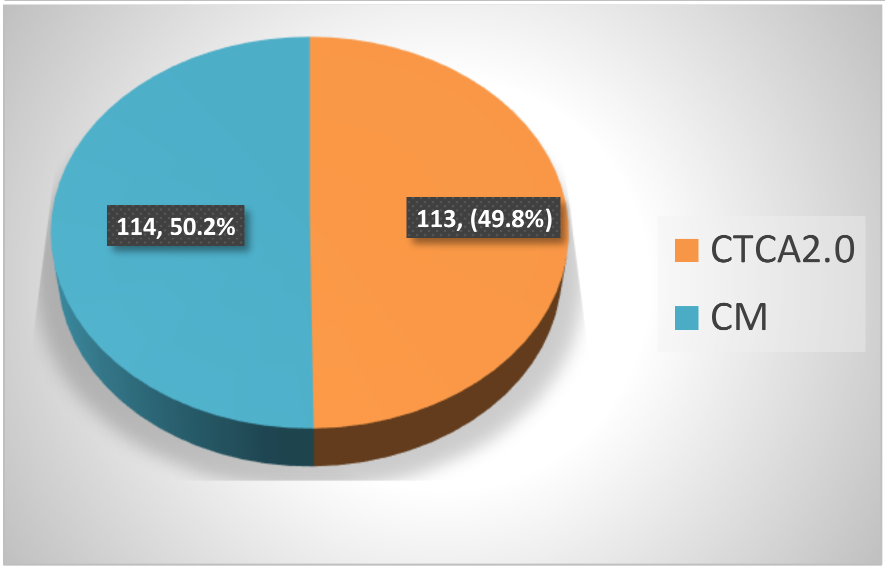


Figure 1: Participants in the experimental and control groups

SS II students were selected because they were settled into school routines and not yet distracted by final exam preparations (WAEC and NECO). The national biology curriculum introduces the digestive system in the second term of SS II (NERDC, 2017). Students already had background knowledge of nutrition and food classes from SS I, which prepared them for this topic. The digestive system is often seen as difficult (Okebukola, 2020), and little research exists on cultural practices or indigenous knowledge related to it (Adeosun et al., 2022). WAEC Chief Examiners' Reports (2020, 2024) also show that students' performance on this topic has been consistently below average.

The **Biology Process Skills Acquisition Test (BPSAT)** was used to measure students' process skills in the digestive system. It contained 30 multiple-choice questions adapted from WAEC Biology exams (2017–2024) and textbooks. Section A collected demographic information, while Section B tested process skills. Each correct answer scored 1 point, and incorrect answers scored 0. The test was reviewed by a WAEC examiner and a university lecturer, who suggested rewording some items and expanding the test to 30 questions. Reliability was checked with a pilot group of 30 students, producing a Cronbach's alpha of 0.81, which shows good consistency. In addition, the **Process Skills Observation Checklist (PSOC)** was used to assess students' practical skills, including observing, classifying, measuring, communicating, inferring, predicting, interpreting data, hypothesising, experimenting, and creating models. Each skill was rated on a five-point scale (1 = Very Low to 5 = Very High). The checklist was validated by a WAEC examiner and a university lecturer, who recommended rephrasing items as clear statements. Reliability was tested using a two-week test-retest with 30 students, yielding a correlation of 0.80, which indicates stable results.

Ethical approval was obtained from the Lagos State University Research Ethics Committee (LASU-REC). Participation was voluntary, and informed consent was collected from students and, where necessary, their parents or guardians. Students were assured of confidentiality, and all data were stored securely on a password-protected computer. Data collection took place in three stages. First, ethical clearance was obtained, and permission to access schools was granted by the Lagos State Ministry of Education. The researcher explained the study to school principals, science department heads, teachers, and students. Second, four biology teachers were trained as research assistants over three sessions. Training covered how to use the CTCA 2.0 teaching guide and how to administer the study instruments to ensure consistency. Third, before the intervention, the BPSAT was administered under the same conditions in both schools. The researcher supervised the test, enforced the 40-minute time limit, and collected the scripts for marking. Scores were recorded and entered into Excel and SPSS for analysis.

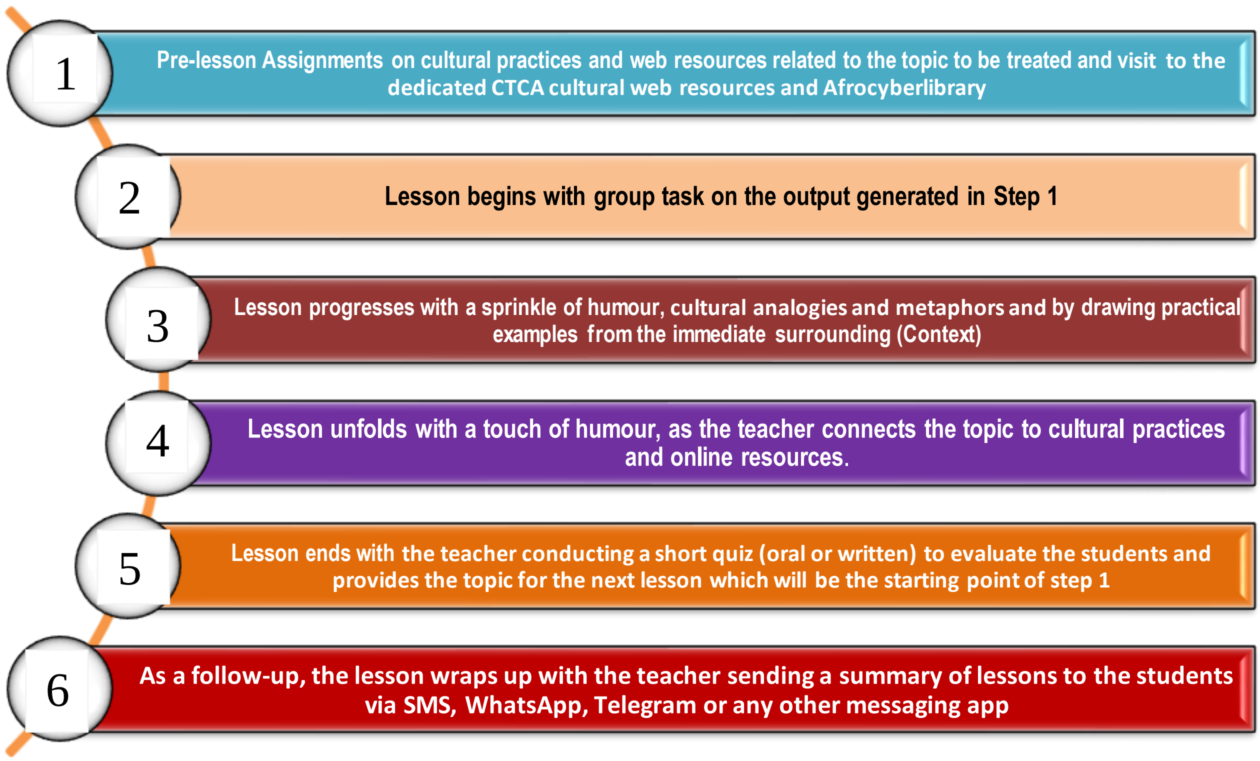
Descriptive statistics (means and standard deviations) were used to summarise student performance. ANCOVA was applied to test the effects of teaching method, gender, and age while controlling for pre-test scores. Assumptions of ANCOVA were checked: normality with the Shapiro–Wilk test, equality of variances with

Levene's test, and regression slope consistency. Although some groups showed slight deviations from normality, ANCOVA is robust when group sizes are balanced and variances are equal. Effect sizes were reported using partial eta squared to show the strength of the results.

The treatment procedure was implemented in Phase Four, where the experimental group, consisting of both science and non-science students, was taught the digestive system using the Culturo-Techno-Contextual Approach 2.0 (CTCA 2.0**)**. The intervention lasted for five weeks and followed six instructional steps as outlined in "Figure 2".

Figure 2: Implementation of CTCA 2.0

(Ogundowole et al, 2025a)



Each lesson period was 40 minutes long, with four lessons conducted per week, resulting in a total of 12 instructional periods for the experimental group. the steps taken were described stepwise below:

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

The students were required to use digital devices such as mobile phones, tablets, or computers to search for information related to the digestive system (see Step 1 in Figure 2). This activity involved engaging with cultural practices, indigenous analogies and metaphors provided by the teacher, which served as the afrocyberlibrary. Second, students were encouraged to consult with family or community members to gather additional cultural practices and indigenous knowledge on the digestive system (indigenous analogies and metaphors were allowed).

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

Based on the pre-lesson tasks, the teacher reintroduced the topic and organised the students into mixed-ability and mixed-gender groups, each comprising up to fifteen members (see Step 2 in Figure 2). In these groups, students shared their findings from the preparatory activities, including summaries on digestive system lessons and cultural/indigenous knowledge obtained from parents or other knowledgeable individuals. Each group leader documented and presented the group's findings (see Figure 3), which lasted approximately twelve minutes. The teacher shared additional indigenous knowledge and cultural practices related to digestion.

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Figure 3: Group Reports

Step 3: Sprinkle of humour with practical examples

The teacher drew practical examples from the school environment with a sprinkle of content-specific humour. Such examples were visible to the students and consolidated learning.

Step 4: The lesson unfolded with a touch of humour

The teacher highlighted the significance of integrating Indigenous knowledge and cultural practices into the lessons. The misconceptions related to cultural beliefs about the digestive system were addressed.

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

The teacher assessed students' understanding through group-based tasks. Students discussed the specimens provided and responded to practical questions within their groups, and they were assessed for process skills using the observation checklist.

Step 6: Summary of the lesson

After each class, a brief lesson summary was sent to the students via the class WhatsApp platform. This was used as a follow-up on the explanation of the digestive system that was given to the students in the class.

Some cultural practices, indigenous analogies and metaphors to exemplify the digestive system

At first, the grinding stone (*"Olo ata"* in Yoruba) was used to explain mastication. A grinding stone is used to grind pepper, grains and other food items. A pestle (*Omo olota*) forcefully moves over the peppers on the mortar (*Olo*), so the peppers change form to fine particles. The parts of the alimentary canal which the grinding stone describes are the mouth (teeth) in mammals and the gizzard in birds. Grinding stones are believed to offer protection against evil spirits and attract prosperity. In some cultures, specific rituals involve grinding herbs to invoke blessings or connect with ancestors. It is also believed that the user's emotional state can affect the food. While these beliefs may lack scientific backing, they reflect the rich cultural heritage.

Another context specific example used was okra grater**,** the use of the okra grater, also known as "irin-la" in Yoruba, explains the breaking down of food. An okra grater is a tool used to shred okra into fine pieces (see Figure 5), making it easier for consumption. It is believed that grated okra aids moistening of the bolus, for easy swallowing through the oesophagus by peristalsis. Nevertheless, there are some superstitions about okra grater. Some cultures suggest that using a grater, particularly a new one, without a proper ritual, can lead to loss of wealth, while others believe that using a grater at night can cause domestic disharmony. While these superstitions can be intriguing, they are not based on scientific evidence.

Figure 5: Okra Grater Exemplifying the Concept of Grinding

Also, mortar and pestle (*Odo-Iyan in Yoruba*) explains the process of chewing during digestion. Pounding in a mortar with a pestle breaks down yam into a uniform texture (see Figure 6), similar to how chewing breaks down food in the mouth into smaller particles. During pounding, water is added to the yam in the mortar to soften them, similar to how saliva mixes with food to soften it.

Figure 6: Pounding Boiled Yam Showcasing Mastication

Also, during most festivals in Africa, it is common to feed a large crowd and the food is expected to be timely as one of the ways to respect the elders. The women place iron spoons or nails in pots of cooking meat (see Figure 7) to hasten softening. This symbolises enzymes in breaking down food particles.

Figure 7: Action of Digestive Enzymes Being Demonstrated With Iron Nails

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The lesson was also contextualized by using the cement and granite mixer (see Figure 11) to explain the churning of food and egestion of waste. The mixer rotates and mixes water, gravel, and cement to form a mixture for construction. Similarly, the stomach, small and large intestine also contract and mix food and consequently form chyme, chyle and wastes.

Figure 9: Granite Mixer in a Construction Site

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During the administration of the Process Skills Observation Checklist (PSOC) to measure how the biology students were observed for process skills development and application. The researcher was physically present during the activity to guide the process and ensure that students engaged with the specimens provided. Students were organised into groups, where they discussed the specimens collaboratively and responded to practical questions designed to elicit specific process skills such as observing, classifying, predicting, and inferring. Each group examined materials, including preserved small and large intestines, the stomach of a rabbit, a model of the digestive system, rabbit teeth, water, and boiled corn placed in a Petri dish. While students interacted with these specimens, the researcher observed their activities and recorded the process skills exhibited by the students. The researcher monitored the groups, clarifying instructions when necessary and ensuring that all students participated in the class activities.

The control group on the other hand was also taught the digestive system using the conventional method for the period of 5 weeks like the experimental group. The lectures provide a thorough theoretical understanding but limited process skills exhibition. The absence of culturally relevant, context-specific examples and group interactions reduced opportunities for students to connect conceptualise biology instruction.

After the five weeks of teaching in both the experimental and control groups, we conducted a post-test using a reshuffled version of the same instrument and this took one week. The test was conducted on different day to each of the groups.

RESULTS

We analysed data collected using mean, standard deviation and one-way Analysis of Covariance (ANCOVA). The ANCOVA was employed because the participants were not divided into groups at random. However, we conducted preliminary checks on the data to make sure that the parametric assumptions were met. The results showed linearity, Levene's test of homogeneity of variances [p<.05], homogeneity of regression slopes (linear slope), normality [p>.05]. Meeting one of these required parametric assumptions, we proceeded to apply the ANCOVA statistics to the test scores of the students in each group.

Research question one sought the difference in the process skills acquisition mean scores of students taught the digestive system with CTCA 2.0, and those taught with the conventional method, is computed using descriptive statistics of mean and standard deviation.

Table 1: Mean and standard deviation of the effect of treatment on process skills acquisition of students in biology

	Group	N	Mean		Mean Diff	SD Diff
			Pre-test	Post-test		
Process skills acquisition	CTCA 2.0	113	9.66	14.87	5.21	0.49
	Conventional Method	114	9.15	11.74	2.59	0.31

Table 1 reveals a difference in the process skills acquisition mean scores of students taught using the CTCA 2.0 and the conventional method. The CTCA 2.0 group performed better, with a higher mean difference of 5.21 (SD diff. = 0.49), whereas the conventional method group recorded a lower mean difference of 2.59 (SD diff. = 0.31), indicating that students in the CTCA 2.0 group recorded higher process skills development compared to their counterparts in the control group. To determine whether this observed difference is statistically significant, null hypothesis one was tested.

Table 2: ANCOVA of the effects of the teaching apprroach

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	832.702[a]	2	416.351	52.438	.000	.319
Intercept	1407.407	1	1407.407	177.259	.000	.442
Method	476.770	1	476.770	60.048	.000	.211
Error	1778.523	224	7.940			
a. R Squared = .319 (Adjusted R Squared = .313)						

Table 2 reveals a statistically significant difference in the process skills acquisition mean scores of students taught the digestive system using CTCA 2.0 compared to those taught with the conventional method [F (1, 224) = 60.05, p < .05]. Furthermore, the partial eta squared value of .211 suggests that the treatment accounted for 21.1% of the variance in the students' exhibited process skills, reflecting a moderately high effect size.

Research question two sought the extent to which students acquire process skills when taught Biology using the CTCA 2.0, to achieve this, this study employed direct observation of students' activities using a five-point scale to rate ten process skills.

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The bar chart in Figure 10 indicates a varied pattern of process skills development. Among the ten process skills assessed, inferring and communicating skills emerged as the most developed, with a mean score of 4.00, similarly, the skill of communicating was also rated high, with a mean of 3.76. The skills of predicting and interpreting data, both with a mean score of 3.38, as well as observing (mean = 3.35), creating models (mean = 3.19), classifying and hypothesising (mean = 2.88 each) and measuring (mean = 2.65). The lowest level of acquisition was recorded in experimenting skill, which had a mean score of 2.06. This implies that a larger cluster of the skills: observing, classifying, measuring, predicting, interpreting data, hypothesising, and creating models fell within the moderate level, suggesting that while students showed notable competence, there remains room for improvement in these areas.

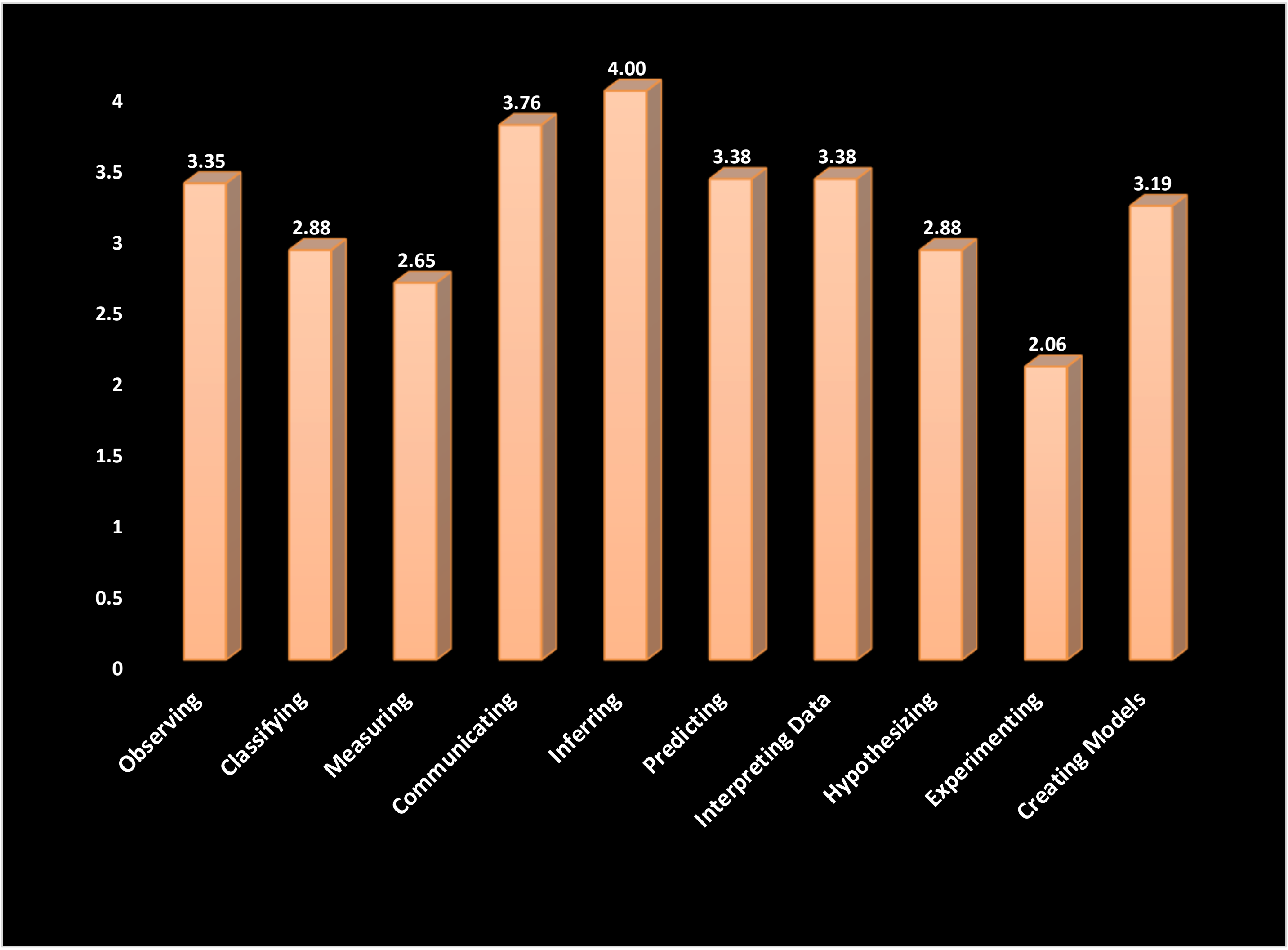

Figure 10: Levels of Process Skills Acquisition in Biology under CTCA 2.0

DISCUSSION

The first research question asked whether students taught Biology with CTCA 2.0 performed differently in process skills compared to those taught with the traditional lecture method. The ANCOVA results (Table 2) showed that CTCA 2.0 helped students develop process skills more effectively. This agrees with Adam et al. (2024a) and Gbeleyi et al. (2022), who found that CTCA improved both subject knowledge and critical thinking. It also supports Darmaji (2022), who showed that linking lessons to everyday experiences boosts learning. In this study, students compared peristalsis to sliding down a playground slide and mastication to pounding yam, making abstract ideas easier to understand. These cultural connections echo Wabuke (2016), who argued that student-centered, context-rich teaching improves reasoning and achievement.

Other teaching methods show similar benefits. For example, Puspita et al. (2025) found that combining Project-Based Learning with Mind Mapping and virtual labs improved process skills by encouraging organisation and exploration. Likewise, Ademola et al. (2025) confirmed CTCA's impact on achievement and problem-solving in nuclear chemistry, showing its relevance across different subjects.

Still, some studies urge caution. Umeji and Achufusi (2025) found only a weak link between process skills and performance in physics, suggesting CTCA's impact may depend on the subject. Similarly, Owolabi (2020) and Adeyemi (2019) reported lower gains when interventions were short, samples small, or CTCA was applied inconsistently. These findings highlight the importance of careful planning and longer exposure to CTCA. Overall, this study confirms that CTCA 2.0 is more effective than lectures in building process skills in Biology.

The second research question looked at how well students acquired process skills after learning the digestive system with CTCA 2.0, based on observations across ten skills. Results showed strong gains in communication, inference, and observation, but weaker development in experimenting and measuring. This matches Ebere and Appolonia (2017), who found that ethnoscience-based teaching improved process skills, and Suman (2020) and Wabuke (2016), who reported that inquiry-based methods enhanced skills like predicting and inferring. Studies by Acarli and Dervişoğlu (2021), Mandasari et al. (2021), and Çelik (2022) also show that using analogies and storytelling helps students grasp complex ideas.

The weaker results in experimenting and measuring reflect broader challenges. Farida et al. (2023) reported similar gaps in Indonesia due to limited lab access, while Ongowo and Indoshi (2013) noted that Kenyan Biology practicals often focus on basic skills, leaving out more advanced tasks like hypothesis testing and experimental design. These findings suggest that while CTCA 2.0 strengthens many process skills, schools need better lab facilities and curriculum reforms to support advanced skills.

Therefore, this study supports constructivist and culturally responsive teaching, showing that connecting science concepts to everyday experiences helps students learn better. Practically, it demonstrates that CTCA 2.0 can improve Biology teaching in Nigerian schools, especially in topics students often struggle with. At the same time, the results highlight the need for longer interventions, stronger lab resources, and curriculum changes to ensure that all process skills, including advanced ones, are fully developed.

CONCLUSION

The findings of this study indicated a significant improvement in process skills among students in the experimental group compared to those taught using the conventional method, suggesting the effectiveness of the CTCA 2.0 in facilitating process skills development. Further findings indicated a varied pattern of process skills development. Among the ten process skills assessed, inferring emerged as the most developed. However, this study reinforces the imperative to rethink science instruction in African classrooms by situating learning within culturally meaningful and technologically enriched contexts. The demonstrated effectiveness of CTCA 2.0 in enhancing students' process skills particularly higher-order skills such as inferring, highlights its potential as a transformative pedagogical model for biology education. Therefore, adopting culturally responsive and context-driven instructional approaches like the CTCA 2.0 offers a viable pathway for equipping learners with the core process skills necessary for scientific literacy and problem-solving in contemporary African societies.

Based on the finding and within the limitation of the study we recommended that:

i. There should be increased awareness of CTCA 2.0 and its implementation among Biology teachers in Lagos State to enable the approach to gain popularity among teachers.
ii. Biology teachers should be trained through workshops and seminars on implementing CTCA 2.0 and on assessment strategies that focus on students' process skills development, thereby enabling regular monitoring and timely interventions to support students' progress.
iii. Parents and guardians should be formally informed about the operation of CTCA 2.0 to encourage their cooperation and support for their children or wards during its implementation.
iv. Textbook authors and publishers should incorporate indigenous knowledge, cultural practices and context specific examples as instructional aids to exemplify Biology concepts and make learning more relevant to students.

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