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A Case for Culturo-Techno-Contextual Approach for Enhanced Academic Achievement in STEM Education

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ABSTRACT

The urgency to develop culturally and contextually responsive pedagogies in science education has become increasingly evident in recent times. In response, various teaching methods have been explored, showing successes in acquiring scientific knowledge. However, a more transformative approach is needed to fulfil the vision of the "Africa we want" as outlined in the African Union Commission's agenda 2063. This advocacy has led to the development of the Culturo-Techno-Contextual (CTCA). The study aimed to conduct a documental analysis to evaluate the effectiveness of the CTCA in improving students' achievement in STEM subjects and explore teachers' perspectives on the efficacy of CTCA in science education. Qualitative approach, incorporating documentary analysis and interviews was employed. For the documentary analysis, a comprehensive search was conducted in electronic research databases from 2019 to 2023, using specific search terms related to CTCA and study design. The interview schedule involved a face-to-face interview with 8 teachers who had used CTCA to teach various STEM concepts. It was revealed that the CTCA possesses remarkable efficacy in enhancing students' academic achievement in STEM concepts. Also, the teachers showed positive perception towards CTCA. It was concluded that CTCA is a potent approach in improving students' achievement in STEM subjects.

1. Introduction

The imperative for culturally and contextually responsive teaching pedagogies in science education has gained increasing prominence, seeking to overcome conventional barriers to profound learning in this field. In response to this critical need, numerous teaching methods have been developed and explored. While these

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approaches have demonstrated certain successes and contributed to the acquisition of factual scientific knowledge (Okebukola, 2020), a more profound transformation is required to fulfill the vision of the "Africa we want," as articulated in the African Union Commission's agenda 2063. For African students to thrive in the digital era, science learning must transcend mere memorization of scientific facts and instead empower them to meaningfully engage with science in a technologically-driven world (Oladejo et al., 2021).

Africa is recognizing the urgency to revolutionize the delivery of science content within its classrooms, aiming not only to foster meaningful learning but also to attract younger generations to pursue science studies. African scholars have long advocated for transformative changes in teaching and learning practices that resonate with cultural and contextual realities (Garvin-Hudson & Jackson, 2018). This advocacy has yielded promising results, leading to the development of a novel teaching approach that targets challenging concepts in science, technology, engineering, and mathematics (STEM) by leveraging cultural knowledge, technology, and the students' locational context to ensure a meaningful learning experience. This innovative approach is referred to as the Culturo-Techno-Contextual Approach (CTCA) (Awwah et al., 2022; Okebukola, 2020).

Culturo-Techno-Contextual Approach (CTCA)

The Culturo-Techno-Contextual Approach (CTCA) represents the culmination of more than four decades of extensive research focused on devising effective strategies for delivering STEM subjects to African students, with a dual aim of promoting meaningful learning and facilitating the practical application of STEM knowledge to address contemporary real-world challenges, both within Africa and beyond (Onowugbeda et al., 2022). Spearheaded by Peter A. Okebukola, CTCA was officially introduced in 2015 at the University of Ibadan, Nigeria. Rooted in a rich theoretical foundation, the approach draws from two prominent learning theories: Vygotsky's theory of social constructivism and Ausubel's theory of advanced organizers. Moreover, CTCA is underpinned by two key philosophies: Kwame Nkrumah's ethnophilosophy and Heidegger's technophilosophy.

The (CTCA) effectively overcomes various barriers in science education, including fear stemming from its unique language and mathematical orientation, limited teaching and learning resources, the abstract nature of certain concepts, and the misconception that science is only for gifted individuals (Okebukola, 2020). CTCA adopts a hybrid approach, drawing on three key frameworks: cultural context, technology-mediated communication, and geographical context(see figure 1). It recognizes the significance of students' cultural backgrounds and integrates cultural influences into science learning, while also leveraging technology for communication and instruction. Additionally, CTCA embraces the unique geographical identity of each school, incorporating relevant local examples and case studies to enhance students' understanding and engagement with science. This comprehensive approach not only promotes meaningful learning but also fosters inclusivity in the science classroom.

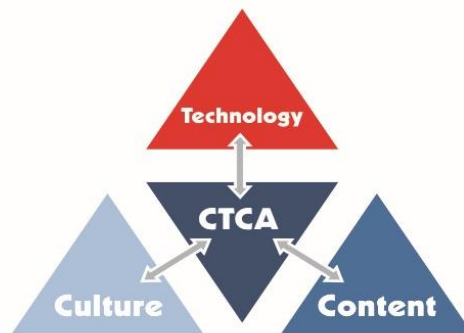


Figure 1. Component of CTCA

The CTCA aims to leverage the richness of diverse cultures to surmount obstacles in achieving meaningful learning outcomes in science subjects. It acknowledges that each individual is a member of a local community, wherein unique systems of thought, knowledge creation, and worldviews have evolved over time (Johnstone, 1997; Ogunniyi, 2013). These knowledge systems have played a crucial role in people's understanding of the natural world (Mawere, 2015). CTCA, therefore, was primarily conceived as a culturally relevant pedagogy, empowering African children to comprehend the science inherent in their surroundings and, consequently, fostering increased participation of African students in various STEM fields.

Rationale

STEM education has posed challenges for students hailing from diverse cultural backgrounds, and African students are no exception to this phenomenon, as evidenced by research conducted by Awaah et al. (2021) and Gbeleyi et al. (2023). For many African students, mastering concepts in STEM subjects has proven to be a formidable obstacle, leading to potential discouragement. Nevertheless, all hope is not lost. There have been noteworthy studies that demonstrate the effectiveness of culturally relevant pedagogies, such as the Culturo-Techno-Contextual Approach (CTCA), in simplifying complex STEM concepts and enhancing students' achievement in STEM subjects (Oladejo et al., 2022; Adam et al., 2021; Onuwegbeda et al., 2022; Okebukola, 2020; Dansu, 2014). These studies serve as compelling evidence for the potential of CTCA as a promising pathway to ensure the delivery of quality STEM education.

Hence, undertaking a documentary analysis of CTCA presents a significant opportunity to assess the effectiveness of this pedagogical approach in enhancing students' achievement in STEM subjects. Such an analysis holds the potential to yield valuable insights and evidence that can inform the formulation of evidence-based policies and practices, thereby supporting the successful integration of CTCA into STEM education. Furthermore, the findings of this analysis will shed light on the efficacy of CTCA in fostering equitable access to quality STEM education, consequently influencing future research endeavors and practical applications in the field of STEM education. Additionally, this study aims to explore the perspectives of educators regarding the effectiveness of CTCA in

fostering improvements in students' academic achievements in the domain of science.

1. Philosophical and Theoretical Framework

This study rests on the pillars of psychological and philosophical theories. The psychological framework incorporates elements from Vygotsky's theory of social constructivism and instructional scaffolding, as well as Ausubel's theory of meaningful verbal learning and advance organizer. Vygotsky's theory of social constructivism posits that learning is fundamentally a social process, wherein significant roles are played by parents, teachers, peers, culture, and society at large. This theoretical underpinning provides essential support for the implementation of the Culturo-Techno-Contextual Approach (CTCA).

In the context of CTCA, learners are encouraged to seek information related to a specific topic from their parents and other individuals possessing indigenous (cultural) knowledge prior to attending the class. Once in the classroom, the approach fosters a social process wherein students interact with their peers, sharing knowledge collectively in groups (see figure 2). Within these group settings, the teacher ensures that learners are scaffolded based on factors such as gender and ability. According to Vygotsky, through the guidance and support of a more knowledgeable peer or teacher, a child can acquire skills or grasp aspects of a skill that surpass the child's current developmental or maturational level (Oladejo et al., 2023).

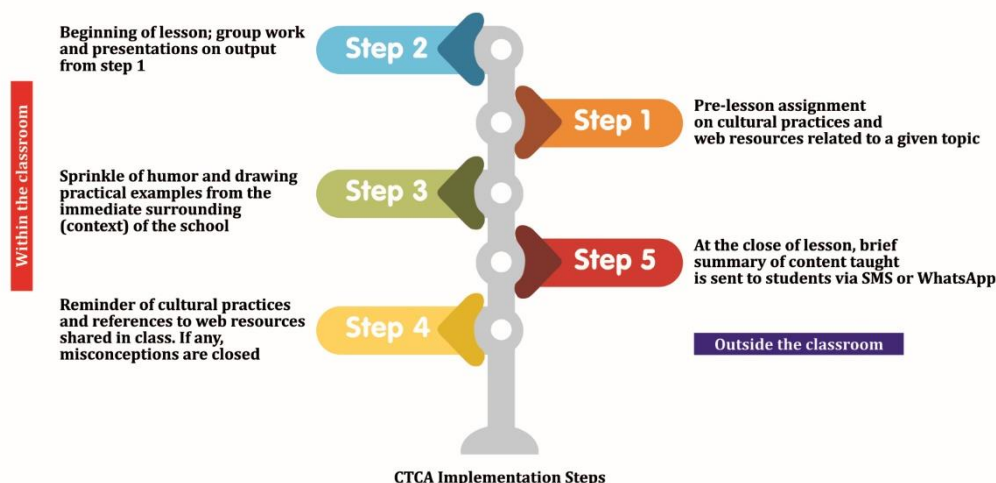


Figure 2. CTCA Implementation Steps

The second theoretical foundation of this study rests on Ausubel's theory of advance organizer. Ausubel (1963) proposed the concept of an advance organizer as a cognitive tool to assist students in connecting their existing conceptual framework with new material or ideas. These advanced organizers represent overarching and inclusive concepts that serve as a scaffold for learning (Ausubel, 1978). This fits with the implementation of Culturo-Techno-Contextual Approach

(CTCA), which necessitates a nexus of prior knowledge related to the subject matter to foster meaningful learning.

The conceptual underpinning of CTCA, with its Afrocentric focus, draws from the philosophical perspectives of Kwame Nkrumah's ethnophilosophy and Martin Heidegger's technophilosophy. Nkrumah's ethnophilosophy advocates for knowledge deeply rooted within the ethnic and cultural context of a particular region, exemplified in the case of Africa. This philosophy aligns with the "culturo" and "contextual" dimensions of CTCA, emphasizing the importance of teaching and learning that is culturally relevant and situated within learners' cultural milieu.

On the other hand, the influence of Heidegger's technophilosophy on CTCA stems from Heidegger's contention that technology embodies a distinct method of revealing the world, enabling individuals to gain control over their reality (Heidegger, 1977). This aligns with CTCA's technological component, which emphasizes the strategic use of technology in the educational process, as depicted in Figure 1.

Furthermore, CTCA's context element finds its philosophical foundation in Michael Williams' Contextualism. This philosophical framework asserts that our actions, expressions, and learning can only be comprehended fully within the specific context in which they occur. When employing CTCA as an instructional approach, it is crucial that the materials and examples used are relevant to the immediate environment of the students, as this enhances their understanding and absorption of the subject matter. The primary objective of this investigation was to conduct a comprehensive documentary analysis, aimed at evaluating the effectiveness of the Culturo-Techno-Contextual Approach (CTCA) in enhancing students' achievement in STEM subjects. Additionally, the study sought to explore teachers' perspectives on the efficacy of CTCA.

2. Methodology

The study employed a qualitative approach which involved a documentary analysis and an interview schedule used to collect data on the efficacy of CTCA. For the documental analysis, relevant studies were located through a comprehensive search of publicly available literature published from 2019 to 2022. The following data sources and search tools were used: (1) electronic research databases, including ERIC, ResearchGate and Academia. Search strategies were adapted to fit the tool used, but all searches were conducted with combinations of two types of search terms, one an education term (Culturo-techno-contextual Approach), and the other a study design term (e.g., control group, comparison group, treatment group, experimental, quasi-experimental). Screening of the research studies obtained through the data sources described earlier was carried out in two stages: abstract screening of the initial electronic database searches and full-text screening of studies that passed the abstract screening. The initial electronic database searches yielded articles (including

duplicates of the same article returned by different databases). Citation information and abstracts of these studies were examined to ascertain whether they met the following four initial inclusion criteria: which are (i) the study appears to use a controlled design (experimental/controlled quasi-experimental (ii) the study reports data on student achievement or another learning outcome (iii) the study must be in African context (iv) studies in the area of science education (iv) articles must be within the last three years. As a result of this screening, 17 articles were retained (see table 1), and 6 articles that did not meet the inclusion criteria were excluded.

An interview was conducted with 8 teachers that has employed CTCA to teach various concept in the classroom(see table 2). The interview took place at a quiet location within the school premises. Before the commencement of the interview, the teachers were reminded that the session was being recorded and the conversation was confidential and strictly for academic and research purposes. The setting for the interview was prepared in such a way that the interviewer and the interviewee were seated facing one another with a table in the middle and two glass cups of water and a recorder placed on it. The setting was planned in this manner to make the interviewee feel relaxed and comfortable and also to secure the interviewee’s confidence and cooperation. The interview took place between 9:00 am and 11:00 am. Each interview session lasted about 12 to 15 min.

3. Results and Discussion

The table below shows the documental analysis of 17 studies that tested the effectiveness of CTCA from 2019 to 2023. The instructional content and subject areas covered in the selected studies included biology (6 articles), physics (3 articles), chemistry (5 articles), mathematics (1 article), and computer studies (3 articles) (See Table 1).

Table 1. Documental Analysis

Subject	Author(s)	Year	Title	Findings	Paper Type
Biology	Onowugbeda et al.	2021	Can the culturo-techno-contextual approach (CTCA) promote students’ meaningful learning of concepts in variation and evolution?	The group taught variation and evolution using CTCA performed significantly better than their control group counterparts	Empirical
	Adam, et al	2020	Exploring the Efficacy of the Culturo-Techno-Contextual Approach (CTCA) in Improving	It was revealed that there was a significant difference in the academic achievement of students exposed to CTCA and those exposed to the lecture method	Empirical

			Academic Achievement of Secondary School Students in Genetics		
	Adeosun	2020	The efficacy of Culturo-Techno-Contextual Approach in improving students comprehension of concepts in biology	The study revealed that the Culturo-Techno-Contextual Approach was effective in improving students' comprehension of digestive system concepts in biology.	Empirical
	Eguere	2019	The impact of the culturo-techno-contextual approach (CTCA) on students' scientific explanations of genetics and ecology concepts	The study revealed, CTCA had a significant impact on students' scientific explanations of genetics concepts and students' attitude towards biology	Empirical
	Ajose	2020	Relative Effectiveness of Culturo-Techno-Contextual Approach (CTCA) in Achievement of Secondary School Students in Energy Flow in the Ecosystem.	There is a statistically significant difference in the achievement of students in the CTCA group and control group in favour of the CTCA group.	Empirical
	Adeosun	2021	The Effects Of Culturo-Techno-Contextual Approach(Ctca) In Improving Achievement Of Secondary School Students In Digestive System	There was statistically significant difference in achievement of the CTCA group and the conventional lecture method group in favour of the CTCA group. Also, Students' perception on the use of CTCA as a teaching method was generally positive	Empirical
Chemistry	Oladejo, et al	2022	Ways To Learning Science Are Undergoing Mutation: Would The Culturo-Techno-Contextual Approach Be An Effective Variant For Learning Chemistry	The experimental group(CTCA)outperformed the control group, but CTCA had no differential impact on students based on gender	Empirical
	Oladejo, et al	2021	In Search of Culturally	The result showed a statistically significant	Empirical

			Responsive Tools for Meaningful Learning of Chemistry in Africa: We Stumbled on the Culturo-TechnoContextual Approach	mean difference between the CTCA and the control indicating that CTCA improved students' achievement in nuclear chemistry. Also, there was no statistically effect of gender on students' achievement in CTCA	
	Ademola, et al.	2023	Impact of Culturo-Techno-Contextual Approach (CTCA) on Learning Retention: A Study on Nuclear Chemistry	A statistically significant difference was found in the retention ability of students taught nuclear chemistry using CTCA and lecture, in favour of the CTCA group. Also, a statistically significant difference was not found for gender The statistical interaction effect of method and gender was not significant	Empirical
	Oladejo, et al.	2023	Face-to-Face and Blended: Two Pedagogical Conditions for Testing the Efficacy of the Culturo-Techno-Contextual Approach on Learning Anxiety and Achievement in Chemistry	The results showed that each of the CTCA groups outperformed the lecture group on measures of achievement. CTCA was also found not to have a significant differential impact on the experimental groups based on gender	Empirical
Computer Science	Agbanimu, et al.	2021	Flowchart and Algorithm as Difficult Concepts in Computer Studies: Can CTCA Come to the Rescue?	The experimental and control groups were statistically significantly difference with the experimental (CTCA group) performing better.	Empirical
	Awaah et al.,	2022	I am a cultural teaching method - I was Successful in the ICT Class in the Global South	There was a statistically significant difference in academic achievement of students taught Python Programming using CTCA and those taught using the lecture method. There was no gender effect on the achievement of students taught using CTCA.	
	Gbeleyi	2022	Impact of culturo-techno-contextual approach (CTCA) on secondary school students' achievement in and attitude to	It was revealed that there was a statistically significant difference in favour of the CTCA group	

Physics	Oladejo, et al.	2023	logic gate Changing the Narratives of Physics-Learning in Secondary Schools: The Role of Culture, Technology, and Locational Context	The result obtained showed that the experimental group (CTCA) performed better than the control group.	Empirical
	Oladejo, et al.	2022	I am CTCA, and this is my first Attempt in the Physics Class - How Will I perform?	The result obtained showed that the experimental group performed significantly better than the control group.	
	Francis	2020	Refractive Index as a Difficult Topic in Senior Secondary Physics: Harnessing the Power of Indigenous (Cultural) Knowledge for its Understanding	It was revealed that there was a significant impact of CTCA on the students' achievement and attitude towards Refractive Index concepts.	Empirical
Mathematics	Oladejo, et al.	2023	The convergence of culture, technology and context: A pathway to reducing Mathophobia and improving achievement in mathematics	It was revealed that CTCA reduces math anxiety and enhanced learning more effectively than the traditional teaching method.	Empirical

The table below shows the themes extracted from the teachers' responses to the interview questions. The findings shows that the teachers exhibited positive views towards the effectiveness of CTCA as a teaching approach.

Table 2. Finding From The Interview

Theme	Summary of findings
Inspiration to employ CTCA.	Responses obtained from the interview participants shed light on their perspectives regarding the Culturo-Techno-Contextual Approach (CTCA). In general, the respondents expressed positive views about CTCA, recognizing its advantages and benefits. The respondents mentioned various inspirations that encouraged them to employ CTCA in the classroom, such as the benefits of CTCA, for research purpose, improve instructional delivery and wanting to see how effective is the approach.
Impact on students' achievement and motivation	Responses obtained from the teachers revealed how CTCA has helped build a better learning platform, and impacted

Challenges faced during implementation	<p>students' motivation in science. the teachers mentioned that the pre-lesson assignments served as an advance organizer to promote meaningful learning. one of the students said <i>"The technology part of CTCA served as advance organizers to the students thus making it easier while learning"</i></p> <p>Findings revealed that the challenges mentioned include students' unfamiliarity with CTCA, difficulty with pre-lesson assignments, limited time, financial constraints, and students' non-attendance to pre-lesson assignments. The respondents provided solutions such as introducing contextual learning, clarifying expectations, extending class time, using humor and examples, minimizing costs, and providing explanations during the first lesson. one of the teachers said: <i>At first, the pre-lesson assignment was a major challenge as students were not able to provide feedback for the assignment. This changed after the first lesson as they understood what was expected from them"</i></p>
Uniqueness of CTCA	<p>Findings revealed that some of the respondents believed that what made CTCA unique was the cultural, technological, and contextual elements of approach. oladejo (pseudo name, chemistry teacher) responded that "The three elements of CTCA are what make it unique. Other strategies focus only on the cultural elements". For some, the inclusion of Indigenous knowledge and active engagement of both students and teachers made the approach unique. for some, the step-by-step procedures and relating each concept to students' culture and context made it unique.</p>
Successful learning outcomes achieved using CTCA	<p>The respondents cited various achievements, such as the positive impact on students' achievement and interest in science, appreciation of culture, improved achievement, enhanced students' achievement in difficult concept in science, breaking down traditional barriers to meaningful learning, enhancing students' cognitive proficiency, and improving the achievement and attitude of secondary school students towards Artificial Intelligence. Habeeb (pseudo name, biology teacher) said that <i>"Students appreciate their culture more and they are able to understand the relevance of culture in science teaching and learning"</i></p>

The research undertook a documental analysis to assess the effectiveness of the Culturo-Techno-Contextual Approach (CTCA) in enhancing students' academic achievement in STEM subjects. Out of the numerous articles considered, 17 met the inclusion criteria, providing sufficient evidence that CTCA has proven effective in improving students' achievements, retention abilities, critical thinking skills, and attitudes towards STEM subjects. The instructional content and subject areas covered in the selected studies included biology (6 articles), physics (3 articles), chemistry (5 articles), mathematics (1 article), and computer studies (3 articles). The analysis of Table 1 revealed that CTCA demonstrated high potency in enhancing students' achievement in STEM subjects, as all reviewed studies reported a positive impact on learning outcomes in this domain. These findings align with previous research conducted by Adam (2019), Ogunbanwo (2019), Oladejo et al. (2021), and Awaah et al. (2022), which collectively provide compelling evidence attesting to the efficacy of CTCA in fostering meaningful learning of STEM concepts.

The congruence between the outcomes of the present study and those of prior studies highlights the significance and influence of culture, technology, and context on students' learning experiences. Particularly noteworthy is the combination of these factors within the Culturo-Techno-Contextual Approach (CTCA), where their interconnectedness appears to yield a profound impact on the learning process. The effectiveness of the CTCA approach can be attributed to the pre-lesson assignments provided to the experimental group prior to each lesson. These assignments, as identified in the reviewed studies, served to motivate students to arrive at the classroom well-prepared and encouraged them to seek knowledge from diverse sources, including their parents or online platforms like YouTube. Drawing from the insights of Vygotsky and Ausubel, this interaction with a more knowledgeable other (MKO) and the utilization of advanced organizers can yield a positive impact on the learning process, as evidenced by the notable improvement in students' achievement in STEM subjects.

In the practical application of the "culturo" dimension within CTCA, educators engaged students in documenting indigenous knowledge and cultural practices associated with the subjects under study. Through this activity, students gained a deeper appreciation for the significance of their cultural practices and established meaningful connections between these practices and the lessons being taught. By doing so, CTCA helped to demystify scientific concepts and make them more relevant to students' ways of life.

Vygotsky's theory of social constructivism serves as a robust foundation for the improved achievement of the CTCA groups, irrespective of the specific pedagogical condition, as evidenced in our review. Prior to each lesson, students were encouraged to engage in interactions with their parents or other knowledgeable adults, delving into cultural practices and local knowledge relevant to the lesson content. Additionally, students were directed to watch related videos on YouTube, which underscores the increasing reliance on technology as a medium for teaching and learning. Upon entering the classroom, students actively shared their findings with their peers, facilitating further learning through interactions and scaffolding within the group. This collaborative process enabled students to learn from their peers, who acted as a more knowledgeable other (MKO), and through this collective effort, they gradually progressed from their zone of "can-do" to a higher level within the zone of proximal development (ZPD). The alignment of these findings is further corroborated by direct statements from an interviewee:

Nasir (pseudo name; 15 years; male; face-to-face group) said the following
I was inspired to use Culturo-Techno-Contextual Approach because of its ability to blend culture and technology to foster meaningful learning. There have been several culturally relevant pedagogies that has been explored to teach science, however CTCA is a culturally relevant pedagogy that is laced with technological and contextual elements. These elements contributed significantly to students' achievement in science. Some of the challenges faced was the student's inability to provide feedbacks for the first assignment. This changed after the first lesson as

they understood what was expected from them. With CTCA, students appreciate their culture more and they are able to understand the relevance of culture in science teaching and learning. The three elements of CTCA are what makes it unique. Other culturally relevant strategies focus only on the cultural elements.

Another key aspect of the CTCA component that logically elucidates the superior achievement of students in the CTCA groups is the integration of contextual examples within the CTCA classroom. As posited by Okebukola (2020), the locational context of each school confers a unique identity, exerting a significant influence on the selection of examples and local case studies employed in science lessons. In support of this, Pobiner et al. (2019), argues that utilizing relevant human examples can facilitate the understanding of basic evolutionary concepts in biology even among upper primary school students. Additionally, Pobiner et al. (2019) assert that the use of pertinent examples fosters active engagement among students in the classroom, thereby explicitly creating an interactive learning environment.

4. Conclusion

The findings of this analysis demonstrated that CTCA exhibits remarkable potency in improving students' academic achievements in diverse fields, encompassing Biology, Chemistry, Physics, Mathematics, and computer science. An essential consideration to highlight is that no community worldwide is devoid of indigenous knowledge and cultural references, which can be effectively harnessed in the teaching and learning process to foster a profound understanding of concepts in STEM subjects, as exemplified in the analyzed study. This universal applicability underscores the cultural-technological-conceptual approach's wider relevance and the broader significance of the study's findings. It is important to acknowledge that culturally relevant approaches to teaching science have been explored in numerous communities across the globe long before the inception of CTCA. Therefore, CTCA can be perceived as an innovative variant of culturally relevant teaching strategies that holds potential for successful implementation in teaching and learning any STEM subject, regardless of the geographical location.

This discovery holds significant implications for science educators worldwide, particularly in the context of advancing science teaching and learning, especially in regions like Africa, where scientific literacy lags behind other areas. Consequently, it is strongly recommended that the implementation of CTCA should extend beyond science subjects to disciplines that are non-science-related, such as commercial and art subjects, in order to ascertain its effectiveness in diverse fields. Moreover, considering CTCA as an additional tool in the repertoire of secondary school science teachers has the potential to foster unity and inclusivity in the pursuit of global scientific literacy, aligning with the ongoing advocacy in science education communities worldwide.

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