

Article

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

Adekunle I. Oladejo ^{1,*} , Peter A. Okebukola ¹ , Nwabuno Nwaboku ², Anthony Kola-Olusanya ³ , Taibat T. Olateju ⁴ , Victor O. Akinola ⁵ , Juma Shabani ⁶  and Ibiyinka Ogunlade ⁷ 

¹ Africa Centre of Excellence for Innovative and Transformative STEM Education, Lagos State University, Ojo 102101, Nigeria

² Department of Science and Technology Education, Lagos State University, Ojo 102101, Nigeria

³ Department of Geography, Osun State University, Osogbo 210001, Nigeria

⁴ Department of Economics, Obafemi Awolowo University, Ile-Ife 220282, Nigeria

⁵ College of Information and Technology Education, Lagos State University of Education, Ojo 102101, Nigeria

⁶ Doctoral School, University of Burundi, Bujumbura 1323, Burundi

⁷ Department of Chemistry, Ekiti State University, Ado Ekiti 362103, Nigeria

* Correspondence: gbadegeshin86@gmail.com

Abstract: Approaches to teaching science are undergoing a mutation and new variants such as the Culturo-Techno-Contextual Approach (CTCA) have emerged and are proving to be more potent than the older variants. This study explored the efficacy of CTCA in reducing learning anxiety and promoting meaningful learning of chemistry among secondary school students by comparing the performance of the two experimental groups with that of the control group. The study employed an explanatory sequential design. The quantitative phase was quasi-experimental, while the qualitative phase was an in-depth interview. A total of 141 senior secondary II students (the equivalent of grade 11) from three purposively selected schools in Lagos State education district V were sampled. The Electrochemistry Achievement Test and revised Science Anxiety Scale which had reliability coefficients of 0.78 and 0.95, respectively, were the instruments used to collect quantitative data, while the students' perception about CTCA interview guide was used to collect the qualitative data. The two experimental groups were taught using CTCA in a face-to-face class and blended learning mode, while the control group was taught using the traditional lecture method. Treatment lasted five weeks after which posttest and retention test (four weeks after posttest) were conducted. Quantitative data were analyzed using one-way MANCOVA, the qualitative data were analyzed using framework analysis. The results showed that each of the CTCA groups outperformed the lecture group on measures of achievement ($F(2,136) = 72.05; p < 0.01$) and anxiety ($F(2,136) = 11.87; p < 0.01$). CTCA was also found not to have a significant differential impact on the experimental groups based on gender. By these results, it was inferred that irrespective of the learning platforms (online or physical), CTCA has the potency to improve students' understanding of chemistry concepts compared to the traditional lecture method. Therefore, within the limitations of the study, it was concluded that CTCA is a viable teaching approach for reducing learning anxiety and promoting meaningful learning of chemistry concepts. Open doors for future exploration were also highlighted.

Keywords: culturo-techno-contextual approach; chemistry; secondary school; anxiety; meaningful learning



Citation: Oladejo, A.I.; Okebukola, P.A.; Nwaboku, N.; Kola-Olusanya, A.; Olateju, T.T.; Akinola, V.O.; Shabani, J.; Ogunlade, I. 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. *Educ. Sci.* **2023**, *13*, 447. <https://doi.org/10.3390/educsci13050447>

Academic Editor: James Albright

Received: 4 March 2023

Revised: 7 April 2023

Accepted: 21 April 2023

Published: 27 April 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Science teaching, science learning, and application of scientific knowledge to solving basic and complex human and societal problems that can foster all-around development at a competitive rate in Africa face formidable challenges that are tasking conventional

strategies. For over four decades, science educators in the continent have been concerned with two major tasks—how to attract young citizens to study science and how to continually improve students’ performance in internal and external examinations [1]. Series of efforts, ranging from curriculum reforms, conferences, roundtable discussions, the conduct of short-term and longitudinal studies, and project interventions such as the EPFL-supported project in Tanzania; the mobile science laboratory kits project in Zambia; the mobile lab for science learning in Burundi, Togo, and other countries under the umbrella of the East African communities; and the early science learning project in Nigeria and Ghana have been explored to ensure success on these two fronts. While notable achievements have been recorded on each of these tasks [2], current demands to provide quality science education for young citizens as aspired and expressed in the Africa Union Agenda 2063 (in pursuance of the “Africa We Want”) show that there is much left to be desired.

In Nigeria, science learning starts from primary school as a general subject such as English language and mathematics. Students at this level, and through the end of junior secondary school, are introduced to basic scientific concepts, culture, and thinking processes. Upon successful completion of junior secondary education, science learning becomes a choice at the senior secondary school, and here is where the challenge begins. As reported by [1], a closer look at the entry registers of students into senior secondary school (taking Lagos as an example) shows that many of these students often opted for science, but within the first year, a significant number of the students are already considering dropping science for other fields of study. By the second year, since the last 10 years, not less than 30% of these initial registrants would have switched to other fields. Why the sudden change of interest is the question to which answers are being sought from different directions. Thus, recognizing this challenge is easy, but providing enduring solutions seems to be the most difficult challenge, nonetheless, we cannot fold our hands.

1.1. Students’ Performance in Chemistry

In spite of the importance of the knowledge of chemistry to our daily activities and the development of our nation, given the highlights in the preceding subheads, not many of the students in the higher institutions in Africa and particularly in Nigeria are in the field of chemistry today. While a minuscule number of them offer chemistry-related courses such as biochemistry, many of these few students perform poorly and show no enthusiasm or good attitude towards learning the courses, and the females are not even doing as good as the males [3]. The case appears to have been rooted from the performance of the students in chemistry at the secondary school level. Students’ achievement in chemistry at the secondary school level, both in internal and external examinations, have not been encouraging over the years. Available statistics on students’ performance in chemistry in the West African Senior School Certificate Examination (WASSCE) from 2010 to 2019 (Figure 1) show that the performance of students is still not at its best, given that there are less than 40% of the expected population in class within these years [4].

Why this persistent unsatisfactory performance in chemistry? A number of studies have been conducted to evaluate and find answers to this question [4–6], and findings from these studies revealed that there are several factors responsible for the underperformance of the students. These factors include but are not limited to a lack of adequate facilities, lack of motivation to learn resulting from anxiety, poor teacher–student ratio, inadequate learning materials, and use of approaches that do not consciously cater to the individual learner’s needs, nor show any respect for their cultural worldview and how it may impact their learning. At the centre of these preponderant reasons is the method or approach used in teaching chemistry. Some scholars have argued that, even if there are adequate learning materials and conducive learning spaces, if the teacher’s choice of teaching method is inappropriate, the expected results may be hindered [3,7].

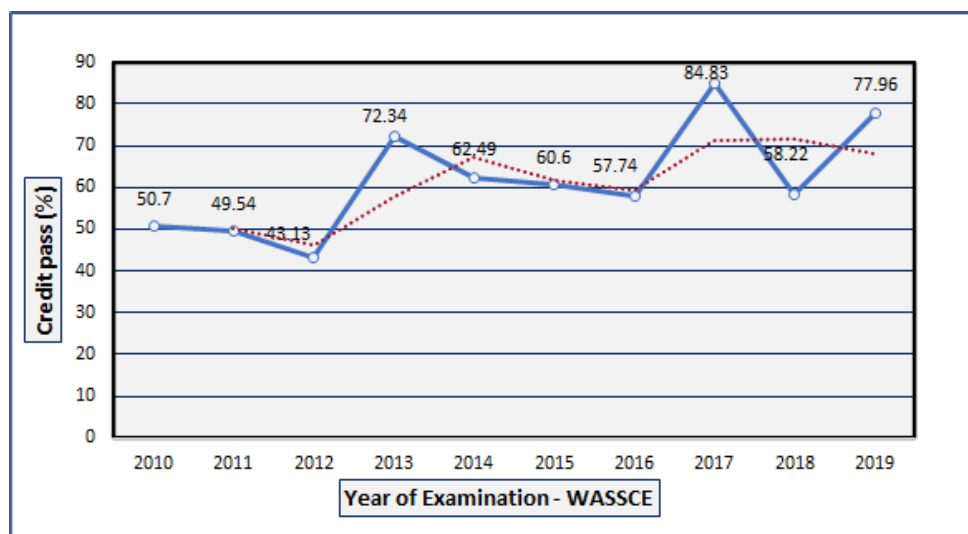


Figure 1. Students' performance in chemistry in Nigeria (2010–2019). Source: WAEC Office Yaba, Lagos.

Several teaching methods and strategies have been employed by teachers in the country to teach senior school chemistry with the intention to make students learn better and understand chemistry concepts in order to improve students' performance in the subject. The effects of teaching strategies such as concept mapping [8], jigsaw [9], and collaboration methods [10] have been extensively investigated and have been reported as effective teaching approaches to improving students' achievements in chemistry. Other teaching approaches such as the use of computer simulations [11,12], concrete-representational-abstract instructional strategy [13], cooperative learning [14], guided inquiry [15], computer animation [16], reflective teaching strategy [17], problem-solving [18], demonstration method [19], 4MAT [20], and card games [21] have also recorded some gains in their implementation in chemistry classrooms in Nigeria.

However, despite these efforts directed towards enhancing the state of chemistry learning and improving students' performance in the different parts of the country, underperformance still persists, and students' knowledge of the subject has not significantly improved. Recent investigations into this problem now point sharply at the commonality of these teaching strategies employed in our classrooms over the years—they are all developed outside the context of Africa and thus may not be as suitable for teaching African children [2,5,22,23]. Thus, the drive for this study is hinged on the urgent need to improve students' achievement in chemistry learning through pedagogical tools that provide a framework in which teachers can help students learn beyond fact memorization and also empower the students to think critically, appreciate the values of indigenous knowledge in classroom learning, and build cultural intelligence in ways that can uniquely motivate them to attain academic excellence at higher levels of cognitive achievement (the Bloom's taxonomy). It is worth noting that students' achievement in this study refers to students' satisfactory performance when tested after a relatively long period of time. This is often referred to as post-posttest or delayed posttest achievement. However, just to be parsimonious, we will use the word achievement throughout this paper.

1.2. Anxiety and Chemistry Learning

To win more students to study science, a significant reduction in students' anxiety level in science classrooms is required. Anxiety in science learning has been described as the feelings of tension and fear that hinder students' involvement with scientific operations [24]. As earlier explained, the desire to improve students' performance in chemistry and other science subjects in Nigeria has geared considerable attention towards understanding how students learn and how to help them to learn meaningfully. For students to learn they must be interested in what they have to learn, otherwise meaningful learning might not take

place. In recent times, our interactions with chemistry teachers, particularly in government-owned schools which housed a larger percentage of the secondary school population in Nigeria, revealed that many of the students do not like to stay in class during chemistry periods. While there could be several reasons for this behavior, the views of most of the teachers we interacted with could be summarized as *anxiety*.

Earlier studies that have investigated this problem have submitted that the use of approaches that are student-centered has the capacity to increase students' active engagement in science learning processes and reduce learning anxiety [25,26]. Other studies have shown that instructional methods that promote group discussion and metacognitive learning [25,27,28], which allow students to control their cognitive processes, can also reduce learning anxiety, and thereby improve students' interest in learning and overall achievement. Thus, a negative correlation has since been established between anxiety and students' achievement in science [29–31] through empirical studies. While several teaching methods with these characteristics have been experimented with and used over time by teachers to teach chemistry in our classrooms, poor attitude to learning and show of lack of interest indicates that the pervasiveness of anxiety still persists.

It therefore appears to us that perhaps, given the rise in the resistance of the various forms of contextually mitigating factors (macrogenic, mesogenic, and microgenia) [32], to business as usual, regarding science teaching and learning in our schools, there is a need to rethink and adopt fresh approaches that can address the persistent problems of the past; approaches that can provide quality science learning for all, prepare the students with capabilities to compete in the global STEM markets, and make them functional and productive members of their societies. Hence the reason to continue the search for more enduring approaches that can sustainably increase students' participation in chemistry learning in Nigerian schools. A scan through the literature on how best to address this problem revealed a sign of hope from the reports of studies that have explored culturally relevant pedagogies in boosting students' achievement and sustaining their interest in learning. Culturally relevant pedagogies have been described as strategies that teachers can adopt to empower students with the ability to attain long-term academic achievement [2,33,34], develop their cultural competence [35,36], and build their capacity to be able to logically critique issues around them [4,37,38]. In these previous studies, culturally relevant pedagogies have been found to promote students' active engagement in science learning and as such may have the inherent capability to significantly reduce students' anxiety towards learning chemistry.

1.3. Gender Difference in Achievement in Chemistry

Gender difference has been identified as a major factor mitigating the general under-achievement of students in STEM courses [32]. Several studies have found that significant differences exist between male and female academic achievement in chemistry, and it is mostly in favour of the male students [39]. This difference is indeed not peculiar to academic achievement, it further extends to participation in science and technology activities. The female participation rate in science and technology in Africa is perceived as low [40], and different initiatives have been implemented to ensure gender balance; however, gender disparity in terms of school enrolment, academic achievement, retention, and completion rates in African schools remains appalling.

Gender difference has been a long-coming issue in students' performance in chemistry, which according to [3,7] is largely due to the non-girl-child friendly methods of teaching adopted by the teachers over the years. The chalk-and-talk method, which is the commonly used method of science teaching in our classrooms, makes the learning atmosphere competitive, making it difficult for most female students to thrive [3]. However, more recent studies have given a glimpse of hope that this narrative can be changed with the use of culturally relevant and technological-mediated methods of teaching to bridge the gender gap in learning chemistry [1,4,41]. This study clings to the testimony of these studies

to explore the potency of the culturo-techno-contextual approach in closing the gender difference in achievement in chemistry.

1.4. Purpose and Research Questions

The problem that this study sought to solve is the persistent underperformance of secondary school students in chemistry and the growing students' anxiety towards learning chemistry [4]. Since 2010, there have been no two consecutive years that Nigeria has recorded improved performance in chemistry in WASSCE; the pattern of results has been one year up and another year down. This sinusoidal wave-like performance where the crest remains unsatisfactory calls for urgent attention. There are also reports [41,42] confirming that a significant number of secondary school students in Nigeria perceive chemistry concepts as difficult. This perception creates fear in the students, distorts their interest in learning when the subject chemistry is mentioned, and, thus, impacts their performance negatively. Our target, therefore, was to explore the potency of the culturo-techno-contextual approach through a face-to-face and blended learning mode on secondary school students' achievements in, and anxiety towards, chemistry. We hypothesized that if students' anxiety resulting from difficulties with learning chemistry concepts is significantly reduced and meaningful learning is enhanced through appropriate teaching approaches, we may be more than one step closer to achieving the "Africa We Want" (AU's agenda, 2063).

The study is guided by the following research questions:

1. Is there a statistical difference in the achievement and anxiety level of secondary school students in electrochemistry when taught using CTCA in a face-to-face class; blended class; and using the conventional lecture method?
2. Is there a statistical difference in the achievement and anxiety levels of male and female students taught electrochemistry using CTCA in the face-to-face class and blended class?
3. What perception do secondary school students hold about the use of CTCA as a strategy for teaching and learning chemistry?

1.5. Why the Culturo-Techno-Contextual Approach?

CTCA is a dividend of over 40 years of quest for a tool that can be used in breaking the barriers to meaningful learning in science subjects. Several methods of teaching science have been found to improve the learning of science concepts. These methods include cooperative learning, concept mapping, discovery learning, demonstration, argumentation, mastery learning, and vee diagramming. Most, if not all, of the methods, singly or in combination, have failed to sustainably promote meaningful learning of science in Africa to a level that can be regarded as significant in the face of contextual mitigating factors. The search for such a method that will foster meaningful learning and elevate the performance of students in school and public examinations led to the invention of the CTC Approach by P.A. Okebukola in 2015.

CTCA is a culturally and contextually relevant approach (method) to teaching and learning in science designed to break down many of the traditional barriers to meaningful learning. Such barriers as fear of science due to its imported and complex language and terminologies; deficit of facilities for teaching and learning; abstract nature of some of the concepts; and perception that science is only for the genius are expected to be melted and broken down by CTCA. The approach as shown in Figure 2 is an amalgam, drawing on the power of three frameworks: (a) cultural context in which all learners are immersed; (b) technology-mediation to which teachers and learners are increasingly dependent; and (c) locational context, which is a unique identity of every school and plays a strong role in the examples and local case studies for science lessons.

Since its official launching as a teaching strategy in 2015, a few studies have tested the efficacy of this approach in Nigeria, Ghana, and Burundi, and they reported positive impacts of the approach not only on the students learning but also on their attitude towards learning [43–45]. However, in recent times, there has been an increase in the number

of studies exploring the potency of this approach in promoting meaningful learning of concepts in STEM subjects, focusing on concepts that have been reported in the literature as difficult to learn for students. In biology, the efficacy of CTCA has been tried out on various concepts including ecology, mutation, variation, genetics, and evolution [2,4,35,46]. In chemistry, the studies include [4,41]. CTCA has equally been tried out on ICT concepts such as logic gates, flowcharts, and algorithms [47] as well as in physics—refractive indices [48].

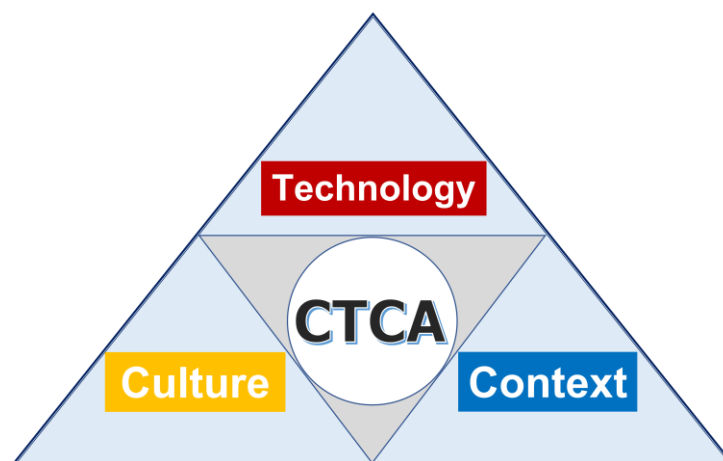


Figure 2. The three frameworks of CTCA.

Notably, each of these studies reported a significant impact of CTCA on the learning attainment of the students, they also reported no gender difference in the performance of the students. This study was therefore conceived to further explore the potency of the approach in breaking the barriers to learning concepts in electrochemistry with two steps beyond the previous studies. We observed that the previous studies based their claims on students' achievement at the posttest (for this reason, we extended our search to retention test/post-posttest) and asked ourselves if the students would still recall what they have learned weeks after the posttest. On the other hand, given the demand of the new normal, we noted that none of the previous studies went beyond face-to-face teaching; thus, we decided to explore the blended learning mode.

1.6. The Blended Learning Mode

Blended learning can be thought of as the use of a combination of different lesson delivery modes for effective teaching and learning. A scan through the literature revealed that the blended mode of learning involves complementing traditional face-to-face classroom learning with online learning delivery modes [49–51]. With the recent pandemic experience accompanied by the massive adoption of different e-learning modes, blended learning has become a more apparent mode of lesson delivery. According to [52], blended learning is an effective mode of teaching which helps to promote students' engagement in the learning process due to the opportunity for different stages of learning experiences. The use of blended learning has been emphasized as a medium for chemistry teaching and learning to gain improved performance among students [53,54].

However, the shift in the learning mode from the traditional face-to-face classroom to an online or blended learning mode suggests that there may be implications of differences in the learning modes on male and female students' performance. It is a societal belief that male children are more skilled in the operations or use of modern technologies than females. However, very few studies have subjected this hypothetical view to experimental investigation in chemistry. It is in addition to this background that this study was expanded to investigate the possible effects of culturally relevant pedagogy and e-learning approaches on students' performance in chemistry based on gender.

1.7. Theoretical Perspective

The theoretical framework for this study draws from Vygotsky's theory of social constructivism and instructional scaffolding and Ausubel's theory of meaningful verbal learning and advance organizer. The author of [55] argues that culture is the primary determinant of knowledge processing and construction. Learning takes place through social interaction among people bound by culture created by their unique strengths, language, and experiences. The author of [56] corroborating this argument asserts that learning as human behavior is rested on interaction with significant others within the social environment influenced by the culture of the people. This significance of culture in knowledge formulation is what CTCA leverages. Vygotsky's theory of social constructivism further asserts that learning is essentially a social process where important roles are played by parents, teachers, peers, culture, and the society at large.

The theory emphasizes social interaction within the family and with knowledgeable others in the society as the basis for a child's acquisition of knowledge and behavior that are relevant to the society. This assertion provides support for the implementation of CTCA. A step in the implementation of CTCA requires the students to seek information about indigenous (cultural) knowledge related to a given topic from their parents, guidance counselor, or any more knowledgeable other (MKO) before coming to class. This process exhibits social interaction with parents playing a crucial role in the development of higher psychological functions of the students. The pre-lesson knowledge obtained from this interaction serves as an advance organizer [57], making it easier for the students to incorporate new information into their cognitive structure during the main lesson. From Ausubel's perspective, this is meaningful learning. The notion of an advanced organizer was proposed by Ausubel as a way of helping students to learn meaningfully rather than rote learning by linking their ideas with new information, concepts, or materials.

CTCA also allows the students to work in groups (mixed-sex and mixed-ability) to share among their peers the knowledge gleaned from their socio-cultural interactions with parents and other resources. This strengthens the social process of interacting with classmates (peers), enabling the students to share and gain knowledge that ordinarily they may not have gained independently. According to Vygotsky, this structure of learning (scaffolding) provides support for a student to learn skills or aspects of a skill that go beyond the student's zone of proximal development (ZPD). The ZPD, as defined by Vygotsky, is the set of skills or knowledge a student cannot do on his/her own but can do with the help or guidance of a more knowledgeable other (MKO). The theory behind these concepts (scaffolding and ZPD), which explains their underlying connection with this study is that, compared to learning independently, CTCA allows the students to learn more when collaborating with their peers or others who have a wider range of knowledge and skills than they currently do. In addition, the use of ZPD requires the teacher to know the current level of knowledge of the students, and that is the thrust of the pre-lesson activities in CTCA.

Vygotsky's sociocultural theory also postulates that social interaction between the teacher and the students is key to students' academic excellence. This social learning theory emphasizes the need for teachers to construct active learning communities and provide an opportunity for managed discussions among the students. Such discussions with substantive comments and meaningful exchange of ideas among the students will result in questions that trigger deep thinking and, in turn, promote meaningful understanding. This aligns with the opinion of [58] who argue that classroom interaction between teachers and students promotes capacity development and enhances the students' quality of reasoning through questioning techniques. CTCA banks on this theory to create an organized learning atmosphere where the teacher, playing the important role of facilitator, maximizes the students' ability to interact with their peers through small group discussion, collaboration, and giving feedback. The teacher actively engages the students in the learning process giving every student an equal chance to submit ideas and make comments.

1.8. What Informed Our Choice of Electrochemistry?

Nigeria and Ghana contribute about two-thirds of the number of candidates from the five West African countries that sit for the West Africa Senior School Certificate Examinations (WASSCE) on a yearly basis for over three decades. Based on this dominant stand, there is an unwritten presumption that whatever affects these two countries regarding WASSCE will possibly affect other member countries. To this end, [41] conducted a survey of difficult concepts in chemistry, sampling about 1300 final-year students from Nigeria and Ghana. Findings from the survey showed that electrochemistry concepts are perceived as difficult by the sampled students. This result is somewhat worrisome and deserves some attention for four reasons.

First, studies [42,59,60] on difficult concepts in chemistry continue to report electrochemistry as difficult for students to learn. Second, as earlier noted by [59], the WASSCE chief examiner's report from 2009 to 2014 acknowledged that students find questions on electrochemistry difficult. Unfortunately, we found that over six years after this report the story remains the same [1]. Third, we also observe that in the last 10 years, questions on electrochemistry concepts form a significant part of the final year chemistry examination for students in Nigeria and other Anglophone West African countries. Implicitly, the recurring poor performance of the students in electrochemistry is a major contributor to the overall long-coming unsatisfactory performance of the students on a yearly basis. Lastly, given the importance of the knowledge of electrochemistry on renewable energy and other advances in modern technology, which is an area of focus of the government of Nigeria and those of other African countries as expressed in the AU's agenda 2063, there is an urgent need to break the barriers to its meaningful learning by the students.

2. Methodology

This study employed explanatory sequential design, a mixed-methods design. The basis for the choice of this design was to provide a better understanding of the research problem than would have been achieved by either a quantitative or a qualitative method alone. The explanatory sequential design allows the user to first collect and analyze the quantitative data and then proceed to collect, analyze, and use the qualitative data to further explain or justify the quantitative results as applicable [61]. The quantitative aspect of the design was pretest, posttest, and delayed posttest non-equivalent group design, which comprised two treatments and one control group, while the qualitative aspect was through in-depth interviews. Based on the understanding of the administrative limitations that surround getting clearance from the state ministry of education to randomly assign students to groups for this study, an intact class from each school represented a group. It is on this premise that the quantitative aspect of the study design was quasi-experimental. For the qualitative phase of the study, 12 students (six males and six females) from the CTCA groups were randomly selected for an interview.

2.1. Participants

With reference to the research design of the study, three senior secondary schools within Lagos State education district V were purposefully selected for this study. Senior secondary school year two (SS2—the equivalent of grade 11) students participated in the study. Each school that participated had a chemistry teacher, a school laboratory, and a record of teaching chemistry to the students in the 2019/2020 and 2020/2021 (first term) academic sessions. The major criterion for eligibility in the study was students' access to internet-enabled devices, particularly after school hours. The schools were considerably distanced from one another to avoid undue interaction that may confound the outcome of the study among the participants. A total of 141 SS2 students participated in the study. The participants were selected from three schools. The experimental group I (CTCA-blended group) had 39 subjects (17 females and 22 males) and was from a private school. The experimental group II (CTCA- face-to-face group) had 48 subjects (27 females and 21 males) and was from a public school, while the control group had 54 subjects (25 females and

29 males) and was also from a public school. Each of the groups was an intact class as randomisation was not feasible due to district administrative regulations. The choice of the private school for the experimental group I was because private schools permit the use of phones, tablets, and personal computers for learning during regular school hours as opposed to public schools. The average age of the students was 15 years.

Going by the structure of the school curriculum, the students had not been thought electrochemistry at the time the study was conducted. The appropriateness of the participants was further justified given that they had spent four terms in the science class, learning contents, processes, and ethics of science, which served as a prerequisite for this study (e.g., oxidation number and the periodic table). In addition, previous studies have also revealed that students at this level are already very skillful in the use of mobile devices and computers for social and other desired functions [44].

2.2. Instruments

The electrochemistry achievement test, which was a multiple-choice items instrument, was developed to collect the quantitative data for this study. The instrument was developed using past questions from the West African Senior School Certificate Examination (2014–2020) and two commonly used senior secondary school chemistry textbooks. The items were constructed following the revised Bloom's taxonomy [62] of educational objectives for its table of specifications, such that all the six levels of the cognitive domain were represented, following the 20 golden rules for multiple-choice questions [63]. The instrument contained 30 discrete items with four options lettered A–D, the options to each question had one key and three distractors. Following are examples of items in the instrument:

1. If a current of 4.5A is passed through a solution of silver salt for 75 min, what is the mass of silver deposited? (A) 22.66 g; (B) 31.45 g (C) 28.16 g; (D) 33.65 g
2. When dilute copper(II)chloride solution is electrolysed, the reaction at the cathode is represented by which of these equations?
3. The set-up of an electroplating experiment is a typical example of (A) a chemical cell; (B) an electrolytic cell; (C) a Daniel cell; (D) a Leclanche cell.

The instrument was validated by three chemistry and two English language teachers with over 10 years of experience in secondary schools. The function of the chemistry teachers was to scrutinize each district item and the corresponding options to ensure that they were not beyond the scope of the content to be taught to the students and were in line with the behavioral objectives outlined in the lesson plans. The language experts helped to ensure that the items were as clear as possible and were void of any grammatical and semantic errors and free from ambiguity. All comments and observations were resolved accordingly before the second draft was trial tested with 20 SS3 students who had been taught the electrochemistry concepts. This trial-testing exercise raised a few issues around time allocation and general face validity. The feedback from the trial-testing exercise was then used to draw the final draft of the instrument. The coefficient of stability of the instrument was determined using the test-retest reliability procedure, and a coefficient of 0.78 was obtained.

The revised science anxiety scale developed by [64] was adopted for this study given its contextual relevance to the current study and population of interest. The instrument contained 20 words that depict states of the mind, ten of which are positive, and the other ten negative. These words were then used as sentences, as in the following examples:

Whenever it is time to learn chemistry, I feel **excited**. Yes or No.

Whenever it is time to learn chemistry, I feel **scared**. Yes or No.

The instrument is scored on a continuous scale of 1–40. Since it is designed to measure negative tendencies that reflect anxiety, if a student said “yes” to a negatively tuned statement, the student scores 2 points. Likewise, if “no” was said to a positively tuned statement, 2 points are scored and vice versa. By this scoring pattern, the total obtainable

amount of points is 40, which shows a very high degree of anxiety, while 20 is the lowest obtainable amount of points if all the twenty words are attended to. The 20 points score shows that a student does not or rarely experience any form of anxiety in the assessed subject. The coefficient of stability of the instrument was determined at 0.95.

The third instrument was the students' perception of the CTCA interview guide (SPCIG), which was used to elicit responses from selected participants on their views about the use of CTCA for learning chemistry. The credibility of data collected through the instrument was ensured through participants' triangulation and member check, which was done through repeated listening to the interview recordings and matching with the unwinnowed transcription.

2.3. Procedures for Implementing CTCA

The two experimental groups (the face-to-face and the blended) were taught using CTCA following its five steps (www.ctcapproach.com; accessed on 5 June 2021) for implementation as depicted in Figure 3. The treatment period lasted five weeks; each week, there was an eighty-minute lesson in each of the groups including the comparison group, which was taught using the conventional lecture method.

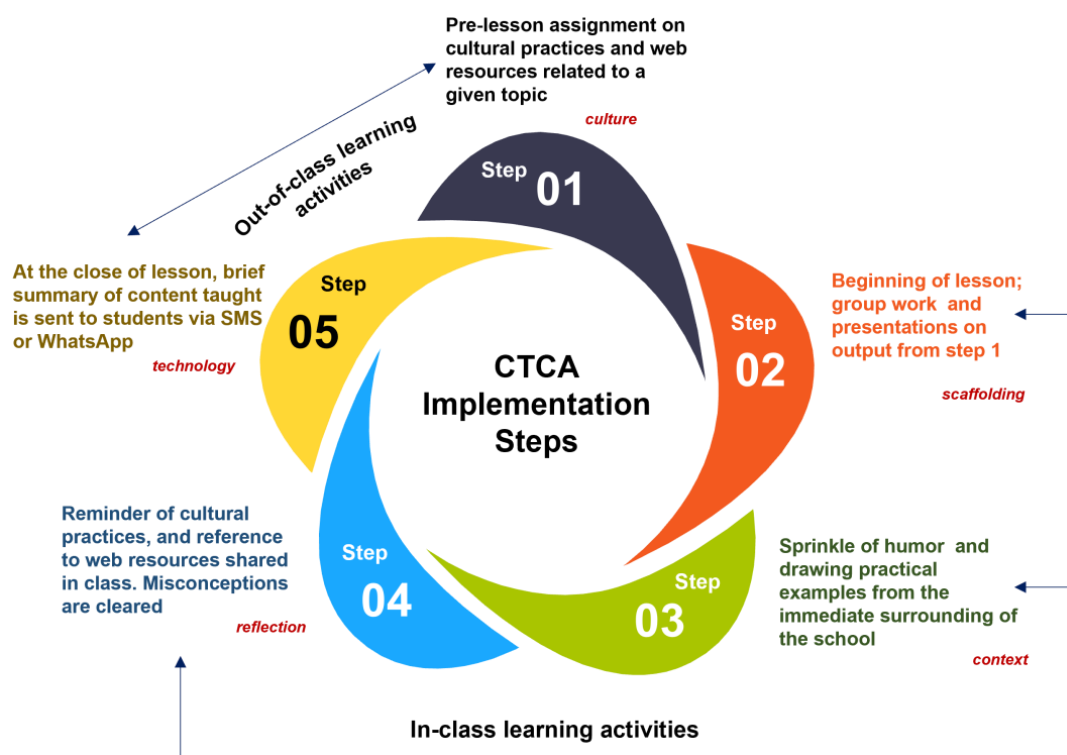


Figure 3. CTCA implementation procedure.

Learning activities were similar for the two experimental groups, an exception was that the blended group had two of their five lessons, online, using the Zoom platform, which was the students' most familiar video conferencing app [65]. The Zoom platform was also preferred because it allows students to group (step-2; group activities)—a necessary function in the implementation of CTCA—through its breakout room feature. The online assessment was carried out using a dedicated learning platform powered by Moodle (www.adekunleoladejo.com; accessed 30 June 2021, Figure 4), unlike the unstructured arrangements (particularly through WhatsApp) used in most schools in Nigeria and many parts of Africa at the peak of the 2020 pandemic [65]. Each of the students in the blended group had a login detail through which they accessed the site, and the teacher was able to track the activity of every student on the site per login.

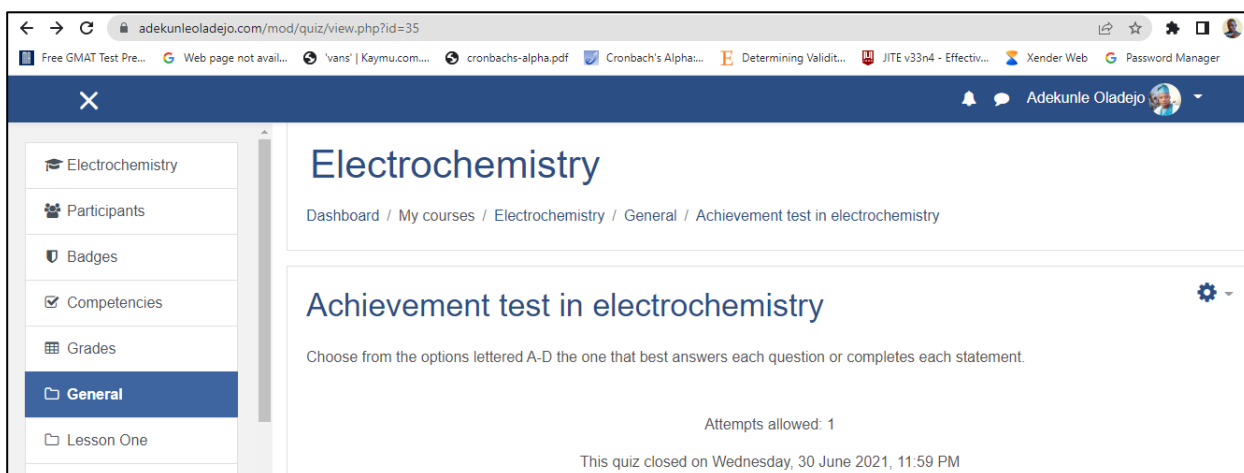


Figure 4. Screenshot of the class site for assessment.

In implementing the CTCA, two days before the start of the lessons (after conducting the pretest), the students were informed of the first topic (electrodes and standard electrode potential) to be learned and were told to complete two tasks: (a) reflect on indigenous knowledge or cultural practices and beliefs associated with the topic and (b) search the web for resources, particularly YouTube videos related to the topic, using their mobile phones or other internet-enabled devices. They were told to discuss the assignments with their parents/guidance counselor or anyone who can help at home. The students were also informed that such reflections would be shared with others at the beginning of the lesson; this is step one of the five steps in implementing CTCA and it reflects the application of Vygotsky's concept of scaffolding and Zone of Proximal Development (ZPD).

However, it is important to mention here that we recognised the possibility of some natural challenges with this step and its related learning activities, particularly because the students do not come from the same home. Differences in socio-cultural background and socio-economic status may set in, to the extent that some students may not have anyone to help, or are willing to help, with related cultural practices and indigenous knowledge, and some students may not have access to the internet. Thus, the group activities that allow the students to interact based on their findings from the pre-lesson assignments and the teacher's rendition in step 2 are expected to bridge this gap. We reckon that by the end of the group discussion and class presentation, virtually all members of the class would have been primed that the unit of information needed to flow with the teacher as the lesson progresses.

At the start of the class and after the introduction of the topic by the teacher, the students were asked to move to their respective groups (students were grouped into mixed-ability, mixed-sex groups of eight to ten students per group with a group leader). Within 10 min, as can be seen in Figure 5, they shared individual reflections on (a) the indigenous knowledge and cultural practices and beliefs associated with the topic and (b) summaries of ideas/information obtained from web resources. In each group, a summary of the cultural and web-based reflections was documented and presented to the whole class by each of the group leaders within 3–5 min (Figure 6). At the end of the students' presentation, the teacher wrapped up by sharing his own cultural reflections on the topic (see Figure 7). This is step 2 of CTCA, and it reflects the application of Vygotsky's concept of ZPD, scaffolding, and learning from a more knowledgeable other (MKO) through peer-share/tutoring.

Students progressed with the lesson following the teacher's guide; the teacher drew practical examples from the immediate surroundings of the school. Examples that the students can physically observe and relate with to make chemistry real (such as soda/bimbo soap, zobo leaf, and street table tennis points, koun blala and kaun obe—potash). This is the "context" flavor of the approach. Some content-specific humor was also sprinkled into

the lesson as it progressed. This is step three of five, and it reflects the use of contextually relevant examples to concretize learning [35].

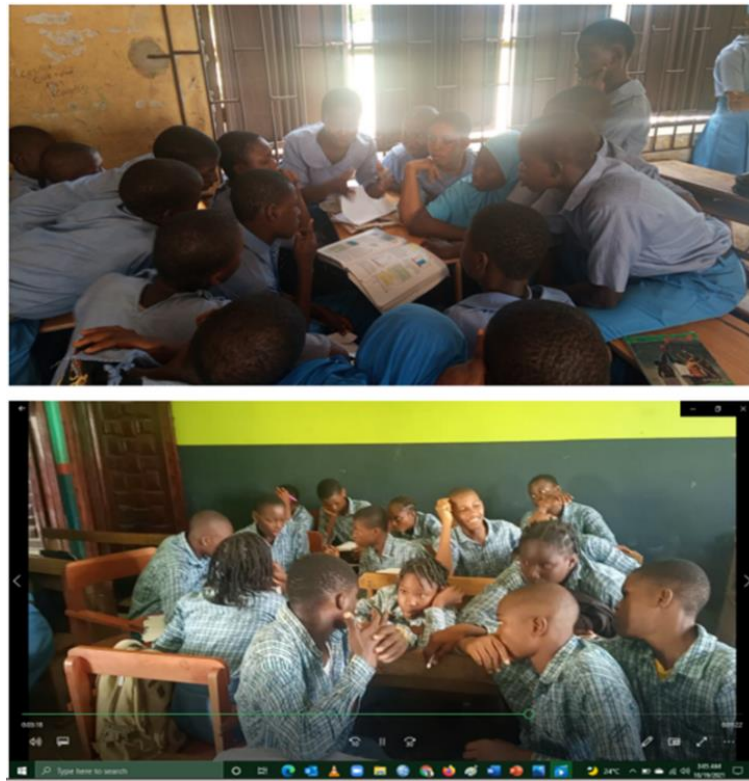


Figure 5. Students having a group discussion.



Figure 6. Presentations by group leaders.



Figure 7. Sample of related cultural practices and contextual examples.

As the lesson progressed, and throughout the duration of the lesson, the students were reminded of the relevance of the indigenous knowledge and cultural practices documented and presented by the groups for a meaningful understanding of the concepts. The areas of misconceptions associated with cultural practices presented by the students were cleared by the teacher. This is step four of five, and it reflects the application of Nkrumah's ethnophilosophy to reinforce learning.

At the close of the lesson, the students were informed to expect a summary of the first lesson (about two pages of SMS) on their phones. The lesson summary (see Figure 8) was sent via bulk SMS and the class WhatsApp platform (step five). They were also informed that after the first lesson, it would become the responsibility of the group leaders to send such a message. Before the class was dismissed, the teacher gave a new pre-lesson assignment to the students on the next topic, which was electrolytic and electrochemical cells, and directed them to carry out the step-one tasks, just as they were for the first lesson.

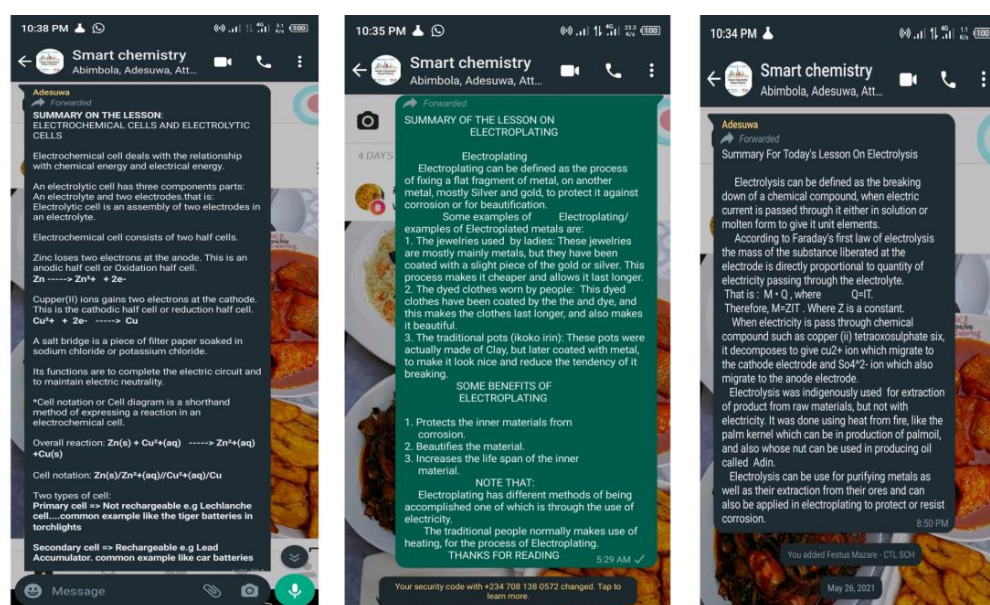


Figure 8. Screenshots of lesson summary sent to the class through WhatsApp.

2.4. Data Gathering and Analyses

At the end of the treatment period, a posttest was conducted for each of the groups using the electrochemistry achievement test and the revised science anxiety scale that was used to collect the pretest data on measures of achievement and anxiety. The comparison group and the face-to-face experimental group had their tests in paper and pencil mode, while the blended group had theirs online using the class site. We do not consider the online platform as a disadvantage for the blended group, since they were familiar with how it worked, given the experiences they had gained during lessons and assignments. The time allocation for test completion was the same for all groups, and since the students in the blended group took their test in class using their gadgets (phones/tablets/laptops) under the supervision of the teacher like the other groups, we were sure that no form of malpractice took place. Two days after the posttest, the selected students who had been pre-informed were interviewed on their perception of the use of CTCA for learning chemistry and their perceived impact of the approach on their understanding or otherwise of the concepts of electrochemistry.

The interview took place at a quiet location within the school premises as authorized by the school's principals. Before the commencement of the interview, the students 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 [66,67]. The interview took place between 9:00 am and 11:00 am (before the long break hour) on different days in the two schools. Each interview session lasted about 12 to 15 min. The timing (morning hours) was to ensure that students were not fagged-out and/or distracted due to long-break activities.

However, because this study is targeted at promoting meaningful learning, we conducted a retention test for the students (i.e., post-posttest, following the same procedure as it was during the posttest) on achievement in electrochemistry four weeks after the posttest without giving prior information to the students. The quantitative data collected was analyzed using multivariate analysis of covariance statistics in IBM-SPSS version 23, given that there were two dependent variables (achievement and anxiety) in the study and the students were not randomly assigned to groups. The pretest scores on achievement and anxiety were used as the covariate to partially exclude the effects of any form of initial difference among the groups on the outcome of the study. The data had earlier been subjected to the required parametric assumption tests to ascertain that it was fit for the identified statistical tool. The tests are, Levene's test of homogeneity, which tells the extent of the variance among the group, and the Shapiro–Wilk test of normality, which tells whether the data collected is normally distributed or not and if the result obtained can be viewed as coming from a true representation of a normal population. Others are the test of the absence of multicollinearity, the Box's M test, and levels and measurement of variables. The qualitative data were analyzed using framework analysis, otherwise known as structured coding, and an interpretative approach, following the principles of explanatory sequential design. Thus, the findings from qualitative data were used to provide an in-depth understanding of the results obtained from the quantitative data [61].

3. Results

The results obtained from the parametric assumption tests carried out on the data collected showed that the data satisfied the assumption of homogeneity of variance among the groups on each of the dependent variables (achievement- $F = 0.99$; $p > 0.05$; anxiety- $F = 2.99$; $p > 0.05$). The output of this test, the Levene test, confirmed to us that the data collected from the groups do not vary significantly. By this, it shows that the variance of each group is almost at par with one another, and, therefore, they are statistically com-

parable. It also confirmed that the data collected in each group for each of the dependent variables were not significantly different from normal (see Table 1).

Table 1. Output of test of normality and homogeneity.

Dependent Variable	Teaching Strategy	Shapiro-Wilk		
		Statistic	df	Sig.
Achievement	CTCA Blended	0.95	39	0.07
	CTCA Face-to-face	0.96	48	0.13
	Lecture method	0.97	54	0.22
Anxiety	CTCA Blended	0.97	39	0.27
	CTCA Face-to-face	0.98	48	0.38
	Lecture method	0.97	54	0.18
Levene's Test of Equality of Error Variances	F	df1	df2	Sig.
Achievement	0.99	2	138	0.37
Anxiety	2.96	2	138	0.06

The Box's M test equally confirmed the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups ($F = 1.89$; $p > 0.05$). The data were also found to pass the test of the absence of multicollinearity, as the results showed that the Pearson correlation (r value = 0.48) for achievement against anxiety was less than the 0.80 benchmark. We also ensured that the observations made were independent of one another. Thus, no participant was in more than one group and, since the study employed intact classes, it was ensured that the schools that participated in the study were considerably distant from one another.

Having met the required parametric assumptions, we proceeded to apply the one-way multivariate analysis of covariance (MANCOVA) statistics to the pretest and post-posttest scores of the students in each group on measures of achievement and anxiety. In research question one, the results obtained showed that there was a statistically significant difference in performance among the three groups in the study (Pillai's trace = 0.60 ($F = 29.35$; $p < 0.01$)). The output of the univariate F (see Table 2) further showed that the observed difference in performance among the groups was in both achievement ($F(2,136) = 72.05$; $p < 0.01$) and anxiety ($F(2,136) = 11.87$; $p < 0.01$), while the partial eta squared (η^2) revealed that only about 15% of the observed variance in the anxiety level of the control and experimental groups is explained by the teaching strategy employed; it accounted for over 50% (effect size) of the variance in the achievement of the three groups.

Table 2. Univariate test results based on teaching strategy.

Dependent Variable		Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Achievement	Contrast	984.68	2	492.34	72.05	0.00	0.514
	Error	929.28	136	6.83			
Anxiety	Contrast	237.65	2	118.83	11.87	0.00	0.149
	Error	1361.57	136	10.01			

The F test tests the effect of teaching strategy. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Since a significant difference was found on both measures (achievement and anxiety), it became necessary to find out which of the three groups was/were responsible for the difference. Therefore, we conducted a pairwise comparison on both measures using the Bonferroni test based on the adjusted mean scores of the three groups (see Figure 9). The results showed that on achievement in electrochemistry, each of the experimental groups outperformed the comparison group. It also showed a CTCA face-to-face group

performed significantly better than the CTCA blended group. On the other hand, the pairwise comparison on the measure of anxiety showed that each of the experimental groups performed better (had a lowered anxiety level after treatment) than the lecture method group.

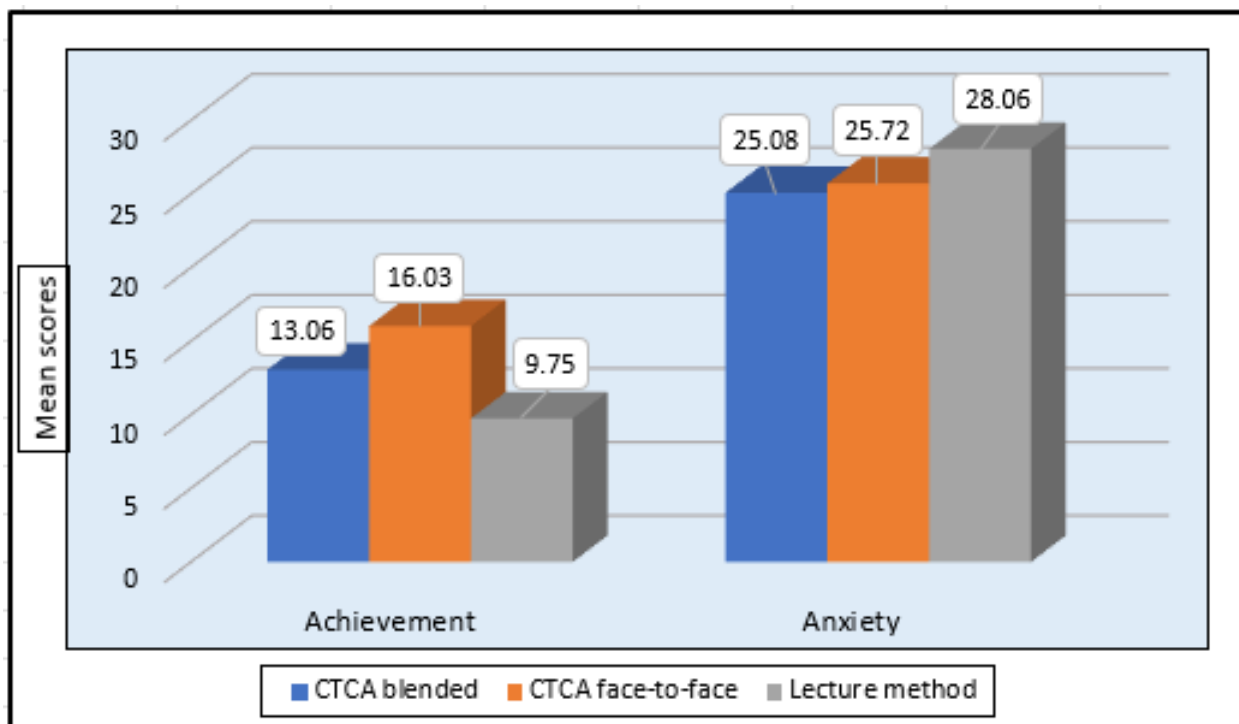


Figure 9. Post-posttest mean scores on achievement and anxiety.

Research question two sought to find out if the intervention (CTCA face-to-face mode and CTCA blended mode) would have a differential impact on each of the groups based on gender. Before subjecting the data to F-test as can be seen in Table 3, the descriptive statistics already showed a comparable mean difference between the mean score of the male and the female students in the CTCA face-to-face and blended groups on achievement and anxiety (see Figure 10).

Table 3. Univariate test results based on gender.

Dependent Variable		Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Achievement	Contrast	4.99	1	4.99	0.66	0.42	0.008
	Error	616.35	81	7.61			
Anxiety	Contrast	26.08	1	26.08	3.33	0.07	0.040
	Error	633.48	81	7.82			

The F test tests the effect of gender. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

The output of the multivariate (Pillai's trace = 0.22 ($F = 11.31$; $p = 0.12$)) and univariate tests revealed that on each of the measures of achievement ($F(1,81) = 0.66$; $p > 0.05$) and anxiety ($F(1,81) = 3.33$; $p > 0.05$), the mean difference between the male and female students did not attain statistical difference. The third research question focused on students' perceptions of the use of the CTCA for teaching and learning chemistry. The data collected have been winnowed and coded. The key findings are presented in Table 4 under the following themes as they relate to the questions attended to by the interviewees. We also

presented additional quotes from the students in the discussion as a way of enriching our discussion of the finding from the quantitative data.

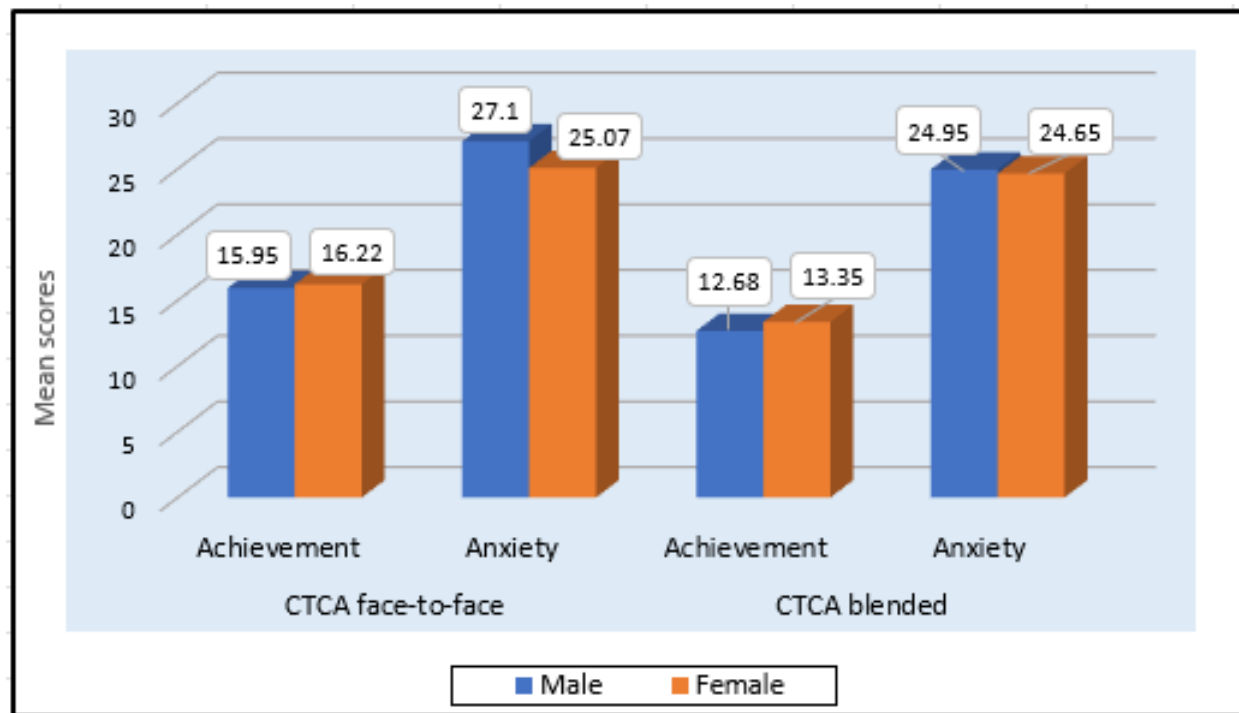


Figure 10. Post-posttest mean scores on achievement and anxiety based on gender.

Table 4. Finding from the interview.

Theme	Summary of Findings
My general view about CTCA	Responses obtained on students' general view about CTCA suggest that the students enjoyed been taught and learning using the approach. Specifically, all the respondents affirmed the approach was better than the conventional method often used by their teachers. One of the online group students said, "if I have my ways, I will say the method should be used to teach all subjects because it gives you clues to every lesson before coming to class".
Learning from parents and YouTube before the class	Findings revealed that the students considered the search for content (videos) on YouTube and learning from their parents or elders around them as a good way to prepare for the class before the lesson took place. For some of the respondents, watching videos was interesting, so having to learn through it could only be fun. Beyond content knowledge, the social interaction enjoyed by students, particularly between them and their parents, was another unique gain that the interviewee expressed.
The most interesting and helpful learning activities	Findings on this theme varied as much as the available options. For some students, the most impactful learning activity was going online to fetch knowledge. Nneka (pseudo name; 15 years; female; online group) gave the following comment: "For me, the online activity is the most helpful and interesting aspect of the approach. The textbooks' definitions are not as clear as the explanations given in the videos". For some, it was contextual examples given by the teacher; while for others, the most impactful aspect of the approach was the group discussion. However, it was noted that about half of the interviewees submitted that the impactful aspect of CTCA was having to search for indigenous knowledge and connect it to class content.

Table 4. Cont.

Theme	Summary of Findings
The group discussions and presentations	Generally, the students' responses revealed that the group discussion was a worthwhile exercise. They submitted that the discussions afforded them the opportunity to share what they knew and learned from others. Interviewees who were group leaders during lessons admitted that the opportunity to present before the class had helped to build their confidence to talk before an audience without being shy. Twelve out of the eighteen students interviewed said that this exercise was their first attempt to make a presentation before classmates and a teacher. Perhaps this was the reason some students considered the group discussions as the most interesting and impactful activity.
Impact of humor and contextual examples on students' achievement	<i>"All work and no play make Jack a dull boy"</i> said, Nneka. Olayinka (pseudo name) also said <i>"the jokes keeps the class lively, and it is the one thing that kept me in the class"</i> . He furthered that <i>"even if you have forgotten what was taught, remembering the jokes will help you remember the topic"</i> . All the interviewees submitted that the jokes told by the teacher made the classes interesting and that the use of examples that they can see around their schools and homes made the topics much easier to understand and remember. When asked why, the most recurring answer was that it affords them the opportunity to relate what they have learned in class to the world around them. Some direct quotes will be highlighted in the discussion section.
Effect of summary of lessons on learning	The summary of lessons often shared before the next class was reported to have served the following purposes: it helped the students to do a quick revision of what was learnt; for students who don't like long notes, it was a preferred substitute; it gave those who missed any lesson a hope to get an overview of what was learned; students who were at one time summarised and shared a lesson summary wore a sense of responsibility; and it was the most interesting aspect of the classes for some. Nasir (pseudo name; 15 years; male; face-to-face group) said that <i>"the summary of lesson helps you to get some better understanding of what was learned in class. Even for those who were in class, when you see the summary, you kind of remember what you have learned before"</i> .

4. Discussion of Results

4.1. Effects of CTCA on Students' Achievement (Retention) in Electrochemistry

The opening question in this study sought to find out if there would be a statistically significant difference in the achievement (retention) and anxiety level of students taught electrochemistry using the traditional lecture method, CTCA blended mode, and CTCA in a face-to-face class. On the measure of achievement, we found a statistically significant difference among the groups. Each of the experimental groups (i.e., the CTCA groups) outperformed the group taught using the traditional lecture method. This result is in accord with the findings of [35,41,44,48,68–70]. These studies tested the potency of CTCA in biology, chemistry, and ICT against the traditional lecture method and found CTCA to promote meaningful learning of the STEM concepts treated. It is important to emphasize that while the findings of these studies provide support for the results obtained in this question, their measure of achievement was based on a posttest. In this study, achievement was stretched beyond the posttest to the retention test, which is a stronger measure of performance based on the time interval between the end of treatment and the test of knowledge gained.

The alignment of the findings of the current study with these previous studies underscores the importance and impact of culture, technology, and context on students' learning, particularly when sandwiched together as it is with the culturo-techno-contextual approach. We conjectured that the better performance of the CTCA groups over the control group on the concept of electrochemistry can largely be explained by factors related to the components of CTCA. The cultural context in which learners are immersed; as explained under the treatment procedure, in implementing the "culturo" part of CTCA, the teacher asked students to document indigenous knowledge and cultural practices related to the topics

that were treated. In carrying out this task, students were able to see that their indigenous knowledge and cultural practices do not count for naught and, directly or indirectly, explained the concept of electrolysis and electroplating as shown in their textbooks, which are filled with only laboratory and industrial examples. Some examples of indigenous knowledge that were shared during the lesson are documented in Figure 7. Students in the CTCA groups came to class already primed with some baseline indigenous knowledge and cultural practices to learn a new topic. For such students, learning a new topic is like swimming down a stream. The indigenous knowledge or cultural practices can be likened to a raft to which the learner clings as a tool to swim down the stream.

Vygotsky's theory of social constructivism also provides a strong base for the better performance of the CTCA groups irrespective of the pedagogical condition. Before any lesson, students were directed to interact with their parents or any adult on cultural practices or local knowledge related to the content and to watch related videos on YouTube (technology mediation, to which teachers and learners are increasingly dependent). On getting to the classroom, the students shared these findings among themselves. This way, the students learned from interactions with parents and through YouTube videos (a more knowledgeable other—MKO). They also learned through interaction and scaffolding with peers and, gradually, they moved without help from their zone of can-do to a higher zone of proximal development (ZPD) espoused by [55,71]. The authors of [57,72] also demonstrated the importance of prior knowledge in learning new concepts. All the pre-lesson activities that the CTCA students were tasked with no doubt would have imparted their learning. Leaning on Ausubel's postulation, these activities serve as advance organizers that steer students to their zone of proximal development (ZPD), which has been theorised to catalyse learning. Supporting this conjecture were the direct words of three of the interviewees which are as follows:

Nasir (pseudo name; 15 years; male; face-to-face group) said the following: *Having to make findings about a new topic before by going on online to watch videos and ask my parents for indigenous knowledge related to the topic gave me a whole lot of courage when I get to class to answer questions. I found the indigenous knowledge to be the most interesting and helpful part. In the sense that it helped me to relate what we learn in class to real life experience it also help me to know what those things stand for and their usefulness. Being a member of a group was very interesting, I get to learn from my friends and also represent them as a group leader, it gives courage and also brings about competition in class because you want to present better than other groups. The group activity create excitement in class and the class was always interesting.*

Adaobi (pseudo name; 14 years; female; blended group) had the following to say: *For me, I like going to the YouTube and I enjoy everything that I do there. I like diagrams, videos, I find them very interesting, so I enjoy that part of the class. The indigenous knowledges and interacting with people are also a nice one. It makes me to know how things around me works.*

Nneka (pseudo name; 15 years; female; online group) said: *Going online and asking my parents about every lesson before the class aided my understanding of the topics because it usually give me a preview of what the topics we are about learn, it makes me understand the topics better. The part of the method that I find most interesting is the indigenous part. Going to find about the cultural aspect on the topics, the local practices. Particularly my findings on electroplating.*

Another aspect of the CTCA component, which logically explains the better performance of students in the CTCA groups even though the analysis conducted already attributed about 50% of the students' gains in achievement to the teaching strategy employed, is the use of contextual examples in the CTCA class. According to [5], the locational context is the unique identity of every school, and it plays a strong role in the examples and local case studies for science lessons. The author of [73] argued that through the use of relevant human examples, even upper primary school students could understand basic

evolutionary concepts in biology. He further argues that using relevant examples promotes students' engagement in the classroom and explicitly creates an interactive learning environment. The author of [74] also concluded that the use of face-to-face objects for illustration in class affords learners a context that enables them to express and expand their cognitive constructs of learning science.

This tenet of the CTC approach, which emphasizes the use of practical examples that are within the learning environment of the students, helps to consolidate knowledge and promote meaningful learning of complex science concepts. It can be recalled that one of the examples used to explain electrolysis was the "battery charger", as popularly referred to within the study area. The students were made to understand that what the battery charger does is to reload a drained car battery when he says "*a ma change omi battery yen ni, ade ma gbe ina lelori*"; by using electricity to split the acid it has changed into anion and cation. The students were so excited to know this, and it was reflected in their responses during the interview. Thus, it is safe to conclude that the use of examples that are far away or do not exist within students' context makes science concepts more abstract and difficult to understand. Contextually relevant examples support learning and the healthy development of a mental construct of ideas [5]. Summarily, what seems to be playing out in the recorded success stories of CTCA-enabled lessons in a face-to-face class or blended mode, is the *opportunity to learn* from more than one source on the same content at a given time.

However, we noted that on the measure of achievement, the result obtained also showed a difference in achievement between the CTCA face-to-face and the blended groups. Students in the CTCA face-to-face group did better than their counterparts in the blended group. One possible reason for this outcome can be traced to the learning mode factor. It would be helpful to recall that the blended mode of learning involves complementing the traditional face-to-face classroom learning with online learning delivery modes. Typically, blended learning provides an opportunity for students to engage in synchronous and or asynchronous interaction and communication and employs the use of advanced technologies such as Moodle, google classroom, and kahoot for online learning, while they still physically attend their schools for the conventional face-to-face teaching and learning. Hence, it is only a matter of available resources and convenience to decide which part of the learning process is rendered online or physically or the number of lessons to be treated online and physically. Evidence on the use of blended learning in the literature has only shown that there is no "one size fits all" model for adopting blended learning.

Indeed, the face-to-face group enjoyed every bit of the lessons and good interaction with the teacher and themselves, the case is not entirely so for the blended group because they had two out of five of their lessons online. While we do not infer that learning online is an inferior mode, the peculiarity of the technology challenges such as poor internet connectivity within the study context must have played out. We noted that during the online sessions, at no time was the class attendance more than 60%. Some students would log in, and 10 min into the lesson they were out, and usually they did not return. The reason for some students is a lack of data to join or rejoin the class, while for others who depended on their parents for phones or computers to join the class when such parents were not at home within the lesson hour, it automatically translated to absence. This experience corroborates the findings of [65] in "delivering high school chemistry during the COVID-19 lockdown: voices from Africa" on the challenges of African countries in delivering online classes. It is worth a mention that this study is the first to experiment with CTCA in an online/blended class with the primary aim of taking the learning of chemistry beyond face-to-face only. It is hoped that over time, through lessons learned from this study and many more, these technology-related challenges will be almost fully surmounted in Nigeria and other parts of Africa.

4.2. Effects of CTCA on Students' Anxiety Level in Learning Chemistry

On the measure of anxiety, the obtained result showed that students in the CTCA groups had a lowered anxiety level after treatment as compared with their colleagues in the lecture method group. No significant difference in anxiety levels was found among the CTCA groups. It is worth noting that there was no significant difference in the anxiety level of the experimental and the control groups, as explained by the pretest data, until after treatment. While there could be other factors responsible for the observed difference, the teaching strategy employed in the experimental groups appeared first on the list of suspects. This result shares semblance with the findings of [2,75]. Both studies found CTCA as an active agent that promotes students' interest in science learning. Similar to this outcome was the finding of [76] on the effect of kitchen resources in Calabar on chemistry students' interest in learning. Logically, an increased interest in learning a subject is directly proportional to a decreasing anxiety level of students in the subject.

The feedback from the postmortem conducted on this result revealed the following possible causatives: the use of technology, the group discussion and presentation, the pre-lesson assignments, the interaction on the class WhatsApp platform, and the jokes given by the teacher. Could the use of technology reduce students' anxiety levels in their learning processes? Oh yes it can, and this is one way it could. Today's learners are natives of the digital world, they speak the language of the computer and the internet because it is the world into which they were born, and so they find ease and wear happiness doing "their things" when it is technology-enabled. Have you not observed that our children never learned how to use the TV and DSTV remotes at home? We just knew that they were using them and so perfectly, even beyond our imaginations. Have you not observed how happy they are the moment they lay their hands on their parents' phones and quickly want to either play games that no one taught them how to play or chat with friends on social media? It is because they do not find *fear* in its usage, operations, and whatever they do with it. Therefore, weaving their learning activities around technology is like laying blocks on an existing foundation, and through this, we killed two birds with one stone, we helped the students to learn in a way that they prefer to and pushed them away from using the gadgets for unhealthy things.

"Ordinarily, most students do not visit YouTube to watch video lessons of topics learned in school. The greater attraction for them being musical and entertainment movies. Sadly, some venture into pornographic videos. Since these students already have some appetite for YouTube and technical expertise for retrieving and watching its videos, the idea in CTCA is to ride on the back of such interest and steer the students towards watching lesson-related videos" (Okebukola, 2020).

During the interview session, Nasir said the following: *"Being a member of a group was very interesting, I get to learn from my friends and also represent them as a group leader, it gives courage and also brings about competition in class because you want to present better than other groups. The group activity create excitement in class and the class was always interesting"*. This response pattern was similar for most of the interviewees when they were asked to share their experiences in their groups. It was clear that the students found the group discussions very interesting, some reported that it was easier for them to learn or ask questions from their friends than the teacher, so, happily they can clarify what they are taught by classmates than remain silent forever. We noted that in the responses of nine out of the twelve students interviewed, a statement summarized that it was during the electrochemistry lessons that they made their first attempt to do a presentation before their classmates and the teacher. For such students, through active participation as depicted in Figure 11, the anxiety (being scared) to talk in class or ask questions if the need arose seemed gone and may so be gone almost forever. As Cisse said, *the presentations sprouted a lot of happy moments in the class, clapping and some noise to say well done to the presenters made the classes lively and free from boredom, sadness, or lack of excitement, all of which are factors contributing to anxiety.*

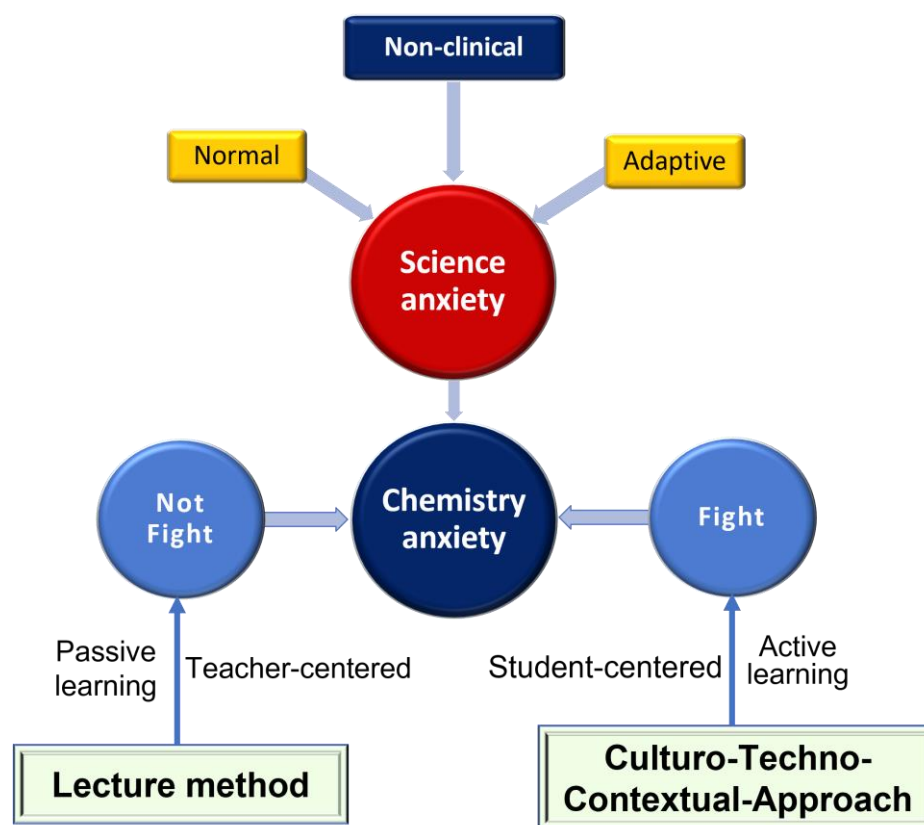


Figure 11. Chemistry anxiety and CTCA.

For students in the CTCA groups, coming to class prepared means no reason to be afraid. It is like a student who has prepared well for an examination has no “exam fever” because he/she is confident in the preparation. For students in the CTCA group, the pre-lesson assignment knocks down anxiety on four fronts; most of the students were excited to come to class to share what they had found as indigenous knowledge or from YouTube about the topic with group members and the entire class; some students were hoping to come to class to get ideas from friends because they were unable to fetch any information; some students could not wait for the class to start because they got some clarifications to make from their friends and the teacher; and, above all, through mental scaffolding which enhances the understanding, findings from the pre-lesson tasks serve as an advance organizer for the CTCA students to build the new incoming information on. According to [1], what deters the students from wanting to attend lessons in chemistry is that they find it difficult to understand the concepts being taught, and hence, when the bell rings and it is the period for chemistry, the students’ hearts crack and they learn in fear.

Even the lion tends to be friendly with whomever it often sees, the dog barks less at you if it sees you often and you also become relaxed around either of them as they extend their hands of friendship. For students in the control group, the teacher is only available to the students as the timetable dictates. After the class, the teacher–student interaction, which ordinarily was feeble, gets suspended until the next class. The students rarely have the opportunity to discuss their subjects among themselves at the end of a class, nor within school hours, because the school timetable has no provision for such, and not after school, because such a common front does not exist. As such, the boring and unfriendly state between the teacher and the students remained as it was almost throughout the period of the treatment. On the other hand, students in the CTCA had the advantage to further their discussions with the teacher and among themselves after a class session and before another through the class WhatsApp platform. With this opportunity, the students became friendly with the teacher and vice versa. There was a moment when a student asked a question on

the platform, and the reply given was that it would be discussed in the next class, and it was. Directly or indirectly, this opportunity must have had a positive impact on the anxiety level of students in the CTCA groups.

As depicted in Figure 11, we hypothesized that teaching approaches that are student-centered, which creates room for a relatively adequate interaction time between the students and the content, students and the teacher, and among the students themselves, may not only improve performance but also have the capacity to fight the learning anxiety that has already been developed by the students for various reason.

A class that is filled with excitement and happy moments is free from fear, boredom, sorrow, sadness, anxiousness, and scariness, as expressed by Cisse. Students in such a class are most likely to be relaxed, calm, and delighted and they learn in a joyful atmosphere. Expectedly, they should be far from anxiety. This is what happens in a CTCA class, where the teacher uses humor (jokes) to sustain the students' interest in class as the lesson progresses. During the interview sessions, a student commented that *"the joke aspect is about the most interesting part of the class oo, ha, if you should remove it, I can even stop coming to the class"*. This statement is reflective of the philosophy in an adage which says, *"ti a ko ba tori epo je isu, aama tori isu jepo"* (meaning, if we do not eat yam because of palm oil, we can for the sake of palm oil eat yam). After all, some people pay thousands of naira just to listen to jokes and free themselves from worries, why then should teachers not use it in class to sustain students' interest in learning? In agreement with the findings of [2] on the impact of humor on students' performance in biology, experience has shown that beyond anxiety, whatever pleases, teaches effectively.

4.3. Effect of CTCA on Students' Achievement (Retention) and Anxiety Levels Based on Gender

The second research question focused on finding if the female students in each of the CTCA groups would outperform their male counterparts (or vice versa) on measures of achievement and anxiety, such that the difference in their performance would attain statistical significance or not. Our findings revealed that on both dependent variables, no statistically significant difference was found between the male and female students. Thus, male students in each group did not do much better than the females in the achievement test and anxiety-level test. These findings tally with that of other studies [41,68,69]. These studies all took place at different times and locations, yet they all reported to have found no difference in the performance of male and female students sampled. A similar trend was reported by [4,47,64]. The results of these previous studies are comparable with the current study in that they all sampled secondary school students, focused on difficult concepts in STEM subjects, and used circular schools; however, unlike this study, which explored blended learning mode, they all limited their engagements with the students to face-to-face only.

It can be recalled that CTCA operates on a five-step implementation process, it was hypothesized that the active agent, which prompted the observed gender equity in learning and performance, is hiding within these processes. In step 1, all students were saddled with the same tasks: find indigenous knowledge related to topics and visit YouTube for related videos. These assignments were for females the same as for male students in the class; in this study as well as in the studies cited. Based on the sample characteristics, over 70% of the participants were from the same cultural background, the cultural information they fetched was not too different from one another, and because the process of collecting/collating the related cultural practices involved a form of storytelling or narration, the female students were not disadvantaged [7].

On the use of YouTube for information, there was no difference between the videos available to either party; whatever video lessons the males took, the females too had an equal chance of having the same. YouTube is one of the most visited social media platforms in Nigeria. As of the third quarter of 2020, *statista.com* reported that 81.6% of internet users in the country visit YouTube, which made it the 3rd most used social media platform in Nigeria behind WhatsApp (another social media agent in this study) and Facebook, whose

ratings were 93% and 86.3%, respectively. Given this popularity, several studies in Nigeria had investigated the effect of YouTube on teaching and learning [77–82].

Each of these studies reported no statistically significant difference in the perception of male and female students about the use of YouTube for teaching and learning purposes. Therefore, the use of YouTube videos as a primer for meaningful learning in CTCA is not only proving to be an effective strategy but also a non-gender stereotyped one. Notably, and as reported by [1], since 2015 the literature is showing that teaching–learning strategies that involve the use of modern technologies, social media, mobile phones, and computer simulations are becoming increasingly popular in bridging the long-coming gender difference in students' achievement in secondary school chemistry [5]. Today's students are generally categorized as visual learners, they enjoy more what they can see as compared to what they can read. Who goes to the library anymore? Recently, book authors (hard copy or electronic) have realized this fact and have begun to adopt other strategies such as vBooks to pass across their messages. Who wonders why students from upper primary classes can narrate an entire season of 10 to 15 episodes of a film series? It is because they enjoy watching whatever the screen projects and are able to store a large amount of information through their sense of sight. This is true to the common saying that *what I see, I remember*.

"We are a visually literate society, three R's (read, write and arithmetic) are no longer enough. Our world is changing fast, faster than we can keep up with our historical modes of thinking and communicating. Visual literacy the ability to both read and write visual information; the ability to learn visually; to think and solve problems in the visual domain will, as the information revolution evolves, become a requirement for success in business and in life". Gray (nd).

Factors mitigating the performance of female students in STEM subjects have been categorized into school and non-school factors [3]. While the non-school factors border around social-cultural issues, the school factors, which include the nature of science and gender-biased curriculum, principally emphasized that the teaching strategies used by STEM teachers play a major role in determining the performance of the girl-child and her future interest in a STEM career [47]. The author of [3] noted that traditional science classrooms/lessons are always competitive, however, female students thrive better in a cooperative learning environment. Thus, the use of CTCA creates a relatively better landing for female students to perform better than they were and even match the male students over time through the group discussion feature in step 2 of implementing CTCA.

On this note, we hypothesized that the interactions and cross-fertilization of ideas that took place during the group discussion sessions may have directly or indirectly played a significant role in the performance of the female students, which, in this case, stood at par with their male counterparts. In recent times, and as science educators continue to pay more attention to the gap in male and female students' performance in achievement and attitude to chemistry, strategies that foster active participation of both male and female students in class through student–student interactions and discussions are proving to become effective antidotes to bridging the long-coming gender difference in achievement in secondary school chemistry [6,59,83].

When students are made to learn from themselves, by providing help for another, or by learning from the teacher, they engage in what is known as instructional scaffolding. Scaffolding helps students to expand their learning coast and acquire more knowledge and skills than s/he would have been able to without support (the scaffold). As noted by [5], the theory behind instructional scaffolding is that when compared to learning by oneself, students learn more through collaboration with others who have a wider range of skills and knowledge than the students currently do. Supplementing the foregoing argument on the possible reasons for which there was no significant difference in the achievement of male and female students in each of the CTCA groups, the contextual examples given in class to drive points home were accessible to all students (male or female; with or without adequate learning materials) and devoid of being gender stereotypic as compared to textbook examples, which were foreign and gender biased.

5. Conclusions

No community around the world is devoid of indigenous knowledge and cultural referents [5]; this can be explored in teaching and learning to foster a meaningful understanding of concepts in STEM subjects as done in this study. This explains the universal relevance of the culture-techno-conceptual approach, and thus the wider relevance of our findings. It is also worth noting that culturally relevant approaches to teaching science have been explored in several communities around the world [33] long before CTCA was invented. CTCA can therefore be seen as a new variant of culturally relevant teaching strategies that can be adopted for teaching and learning any STEM subject in any part of the world.

We conjectured that as science communities around the world continue to advocate for inclusive science learning and equity in participation and ownership, so will the strategies for teaching and learning science continue to mutate. New variants such as the culturo-techno-contextual approach, which are capable of overcoming the weaknesses of the older variants, will continue to emerge and reshape the ways we communicate and teach science. In addition, the demands of the new normal and the technophilic (technology-loving) learners will also continue to impact teachers' modes of lesson delivery to foster favorable pedagogical conditions that can meet the needs of the learners even as they become more technology dependent. Given that the focus of this study was to compare the performance of the two experimental groups with that of the control group, the results presented show that irrespective of the learning platforms (online or physical), CTCA may be considered effective in improving students' understanding of chemistry concepts as compared to the traditional lecture method.

Therefore, our findings have extended the validity of CTCA (as established by previous studies) as an approach that can be used to promote meaningful learning of STEM subjects among secondary school students beyond face-to-face to online engagement. The use of a dedicated online platform powered by Moodle for ensuring structured assessment of students is another contribution that this study puts forward, particularly for communities that are not tech-sophisticated as the context of this study. Even though it may not be its best, it is a better option than the unstructured arrangement that was devoid of students' assessment, which we rushed into at the peak of the 2020 pandemic. If the relatively low-tech communities continue to explore more structured ways of online lesson delivery and assessment, we will not only be preparing our students to be competitive in the global market, but we will also be better prepared in terms of availability and technical know-how to ensure no break in students learning should the world have to go lock-down again in the future.

The feedback (just in conversation) we got from the teachers at the experimental schools further confirmed to us that the use of CTCA had a significant positive impact on the students' attitude towards chemistry learning, particularly through regularity and active participation in learning tasks in chemistry class during the treatment period. The no gender difference in achievement that was recorded in the previous studies on CTCA further confirms the potency of the conceptual frameworks (culture, technology, and locational context) of the approach in bridging the gender-based gap in performance in chemistry. We anticipate a significant boost in female STEM professionals in Nigeria and Africa in a few years if this trend in performance continues. It is in light of the findings of this study and those of previous studies on CTCA that we are beginning to see the culturo-techno-contextual approach as an egalitarian pedagogy.

Limitation and Future Direction

A limitation of this study can be found in its scope. It focused on only electrochemistry among the nearly twenty broad themes in the secondary school chemistry curriculum. The period of treatment was also considered not long enough to see if the observed excitement of the students in chemistry learning will last for a full term and beyond. We also acknowledged the difficulties encountered by the students in the blended learning

group in respect of internet disruption during the online live lessons. Given the number of schools within the study area and the targeted population, we consider the sample size of the study as relatively small. One implication of this is the constraint it places on the generalizability of the findings of the study. We, therefore, noted the need to advance studies in secondary school chemistry on the use of CTCA beyond the scope of the current study. In the future, we hope to explore the potency of the approach on other variables (such as learning styles) that researchers have identified to impact students' learning in science. Fully online learning is another variant of pedagogical condition that we intend to subject the use of CTCA to as events unfold.

Author Contributions: Conceptualization, A.I.O., P.A.O. and J.S.; methodology, A.I.O., P.A.O. and N.N.; validation, T.T.O., V.O.A. and I.O.; formal analysis, A.K.-O. and T.T.O.; data curation, V.O.A. and I.O.; writing—original draft, A.I.O. and T.T.O.; visualization, A.K.-O.; Supervision, P.A.O. and N.N.; funding acquisition, A.I.O., P.A.O. and J.S. All authors have read and agreed to the published version of the manuscript.

Funding: The APC for this article was funded by the Africa Centre of Excellence for Innovative and Transformative STEM Education (ACEITSE), Lagos State University, Ojo, Lagos State, Nigeria.

Institutional Review Board Statement: Not Applicable.

Informed Consent Statement: Not Applicable.

Data Availability Statement: Data generated and analysed for this study are kept in our archive and can be made available by the corresponding author on request. Contact: gbadegeshin86@gmail.com.

Acknowledgments: Sincere appreciation to the authorities and students at the schools that participated in the study. Many thanks to the chemistry teachers who assisted us in administering the treatment.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Oladejo, A.I.; Nwaboku, N.C.; Okebukola, P.A.; Ademola, I.A. Gender difference in students' performance in chemistry—can computer simulation bridge the gap? *Res. Sci. Technol. Educ.* **2021**, 1–20. [CrossRef]
2. Onowugbeda, F.U.; Okebukola, P.A.; Agbanimu, D.O.; Ajayi, O.A.; Oladejo, A.I.; Awaah, F.; Ademola, I.A.; Gbeleyi, O.A.; Peter, E.O.; Ige, A.M. Can the culturo-techno-contextual approach (CTCA) promote students' meaningful learning of concepts in variation and evolution? *Res. Sci. Technol. Educ.* **2022**, 1–17. [CrossRef]
3. Nzewi, U.M. Recent Developments in Gender Issues in STEM Education. YouTube. 2020. Available online: <https://youtu.be/mcbpmMgjis4> (accessed on 22 October 2021).
4. Ademola, I.A.; Oladejo, A.I.; Gbeleyi, O.A.; Onowugbeda, F.U.; Owolabi, O.L.; Okebukola, P.A.; Agbanimu, D.O.; Uhuegbu, S.I. Impact of Culturo-Techno-Contextual Approach (CTCA) on Learning Retention: A Study on Nuclear Chemistry. *J. Chem. Educ.* **2023**, *100*, 581–588. [CrossRef]
5. Okebukola, P.A.O. *Breaking Barriers to Learning of Science: The CTC Approach*; Sterling Press: Slough, UK, 2020.
6. Obikezie, M.C.; Chikendu, R.E. Effect of Cooperative Group Learning Strategy on Secondary School Students' Achievement in Chemistry in Anambra State, Nigeria. *Int. J. Adv. Eng. Manag.* **2021**, *3*, 275–283.
7. Oludipe, D.I. Gender difference in Nigerian junior secondary students' academic achievement in basic science. *J. Educ. Soc. Res.* **2012**, *2*, 93–99.
8. Adesope, O.O.; Nesbit, J.C. Animated and static concept maps enhance learning from spoken narration. *Learn. Instr.* **2013**, *27*, 1–10. [CrossRef]
9. Gongden, E.J.; John, D.P.; Gimba, E.M. Effects of Jigsaw Cooperative Learning Strategy on Senior Secondary Two Chemistry Students' Understanding of Chemical Kinetics in Jos South LGA of Plateau State, Nigeria. 2019. Available online: <http://hdl.handle.net/123456789/3270> (accessed on 22 October 2021).
10. Amponsah, K.D.; Kotoka, J.K.; Beccles, C.; Dlamini, S.N. Effectiveness of Collaboration on Low and High Achieving School Students' Comprehension of Electrochemistry in South Africa. *Eur. J. STEM Educ.* **2018**, *3*, 4. [CrossRef]
11. Okwuduba, E.N.; Okigbo, E.C. Effect of Teaching Methods on Students' Academic Performance in Chemistry in Nigeria: Meta-Analytic Review. *Bulg. J. Sci. Educ. Policy* **2018**, *12*, 418–434.
12. Jabeen, F.; Afzal, M.T. Effect of Simulated Chemistry Practicals on Students' Performance at Secondary School Level. *J. Educ. Educ. Dev.* **2020**, *7*, 119–139. [CrossRef]
13. Ogunleye, B.O. Effects of concrete-representational-abstract instructional strategy on chemistry performance of students with mathematics learning difficulties in Ogun State, Nigeria. *KIU J. Educ.* **2019**, *14*, 135–151.

14. Udu, D.A. Comparative effects of individualised and cooperative learning instructional strategies on senior secondary school students' academic achievement in organic chemistry. *Electron. J. Res. Sci. Math. Educ.* **2018**, *22*, 1–14.
15. Omoniyi, A.O.; Torru, T.E. Effectiveness of Process Oriented Guided Inquiry Teaching Strategy on Students' Performance in Chemistry in Secondary Schools in Ondo State, Nigeria. *Am. Int. J. Educ. Linguist. Res.* **2019**, *2*, 34–38. [CrossRef]
16. Gongden, E.J.; Yame, P.T.; Ephraim, E. Effects of computer animation instructional strategy on students' interest and achievement in chemical bonding in Shendam, Plateau state, Nigeria. *Am. J. Humanit. Soc. Sci. Res.* **2020**, *4*, 304–331.
17. Boris, O.O. Effects of reflective teaching on secondary school students' academic achievement in Chemistry in Ondo State Nigeria. *Int. J. Res. Anal. Rev.* **2019**, *6*, 32–39.
18. Sunday, E.; Ibemenji, K.A.; Alamina, J.I. Effect of problem-solving teaching technique on students' stoichiometry academic performance in senior secondary school chemistry in Nigeria. *Asian J. Adv. Res. Rep.* **2019**, *4*, 1–11. [CrossRef]
19. Achimugu, L. Effectiveness of Enriched Demonstration and Lecture Instructional Strategies on Senior Secondary School Students' Achievement in Chemistry. *J. Contemp. Educ. Res.* **2018**, *2*, 1–9. [CrossRef]
20. Omoniyi, A.O.; Akinsete, A.M. Use of Four Mode Application Technique Learning Cycle Model to Unlock Students' Potential in Chemistry in Secondary Schools in Ondo State, Nigeria. *Int. J. Chem.* **2020**, *4*, 56–61.
21. Bankole, I.S. Deploying card games as tools in learning chemistry concepts in Nigerian Classrooms. *J. Chem. Soc. Niger.* **2018**, *43*, 325–335.
22. Dansu, T.V. Impact of Indigenous Knowledge System and Practices (IKSP) on Secondary School Students' Comprehension and Entrepreneurship Skill in Chemistry Concepts. Master's Thesis, Lagos State University, Ojo, Nigeria, 2022.
23. Gbamanja, S.P.T. Nexus between Science and Culture: A Panoramic View from Sierra Leone. *J. Afr. Cult. Int. Underst.* **2014**, *7*, 16–24.
24. Seligman, M.E.P.; Walker, E.F.; Rosenhan, D.L. *Abnormal Psychology*, 4th ed.; W. W. Norton & Company: New York, NY, USA, 2001.
25. Jegede, O.J.; Alaiyemola, F.F.; Okebukola, P.A. The effect of concept mapping on students' anxiety and achievement in biology. *J. Res. Sci. Teach.* **1990**, *27*, 951–960. [CrossRef]
26. Oludipe, D.; Awokoy, J.O. Effect of cooperative learning teaching strategy on the reduction of students' anxiety for learning chemistry. *J. Turk. Sci. Educ.* **2010**, *7*, 30–36.
27. Hong, J.C.; Hwang, M.Y.; Tai, K.H.; Tsai, C.R. An exploration of students' science learning interest related to their cognitive anxiety, cognitive load, self-confidence and learning progress using inquiry-based learning with an iPad. *Res. Sci. Educ.* **2017**, *47*, 1193–1212. [CrossRef]
28. Cooper, K.M.; Downing, V.R.; Brownell, S.E. The influence of active learning practices on student anxiety in large-enrollment college science classrooms. *Int. J. STEM Educ.* **2018**, *5*, 23. [CrossRef] [PubMed]
29. Akanazu, E.C.; Okoli, J.N. Test Anxiety as Correlate of Chemistry Achievement among Secondary School Students in Imo State. *Unizik J. STM Educ.* **2019**, *3*, 155–165.
30. Oguchienti, C.V.; Opara, I.M. Development and Validation of Chemistry Test Anxiety Scale (CTAS) for Secondary School two Students in Abia State. *East Afr. Sch. J. Educ. Humanit. Lit.* **2021**, *4*, 92–104.
31. Popoola, S.O.; Adedokun, O.O. Computer self-efficacy, computer anxiety, cognitive skills, and use of electronic library resources by social science undergraduates in a tertiary university in Nigeria. *J. Librariansh. Inf. Sci.* **2023**, *55*, 111–122. [CrossRef]
32. Martínez, A.J.G. Science Education: A Sociocultural View. 2020. Available online: <https://www.youtube.com/watch?v=VIVT6xclRuY> (accessed on 8 July 2021).
33. Ladson-Billings, G. Fighting for our lives: Preparing teachers to teach African American students. *J. Teach. Educ.* **2000**, *51*, 206–214. [CrossRef]
34. Underwood, J.B.; Mensah, F.M. An investigation of science teacher educators' perceptions of culturally relevant pedagogy. *J. Sci. Teach. Educ.* **2018**, *29*, 46–64. [CrossRef]
35. Adebayo, I.; Oladejo, A.I.; Okebukola, P.A. Examining the Relative Effectiveness of CTCA in Improving Secondary School Students' Achievement in Genetics. In Proceedings of the NARST 95th Annual International Conference: Unity and Inclusion for Global Scientific Literacy: Invite as a Community. Unite as a Community, Vancouver, BC, Canada, 27–30 March 2022.
36. Warren-Grice, A. Advocacy for equity: Extending culturally relevant pedagogy in predominantly white suburban schools. *Teach. Coll. Rec.* **2017**, *119*, 1–26. [CrossRef]
37. Mensah, F.M. Theoretically and practically speaking, what is needed in diversity and equity in science teaching and learning? *Theory Into Pract.* **2013**, *52*, 66–72. [CrossRef]
38. Young, E. Challenges to conceptualizing and actualizing culturally relevant pedagogy: How viable is the theory in classroom practice? *J. Teach. Educ.* **2010**, *61*, 248–260. [CrossRef]
39. Eya, N.M.; Ezech, D.N. Meta-Analysis of Influence of Gender on Students' Academic Achievement in Chemistry in Nigeria. *J. Chem. Soc. Niger.* **2020**, *45*, 615–619. [CrossRef]
40. Nicia, G.; Luisa, S. A Gender-based Assessment of Science, Technology and Innovation Ecosystem in Mozambique. *Afr. J. Rural. Dev.* **2020**, *5*, 79–95.
41. Oladejo, A.I.; Okebukola, P.A.; Olateju, T.T.; Akinola, V.O.; Ebisin, A.; Dansu, T.V. In Search of Culturally Responsive Tools for Meaningful Learning of Chemistry in Africa: We Stumbled on the Culturo-Techno-Contextual Approach. *J. Chem. Educ.* **2022**, *99*, 2919–2931. [CrossRef]

42. Uzezi, J.G.; Ezekiel, D.; Auwal, A.M. Assessment of Conceptual Difficulties in Chemistry Syllabus of the Nigerian Science Curriculum as Perceived by High School College Students. *Am. J. Educ. Res.* **2017**, *5*, 710–716. [\[CrossRef\]](#)
43. Egerue, I.C. Impact of Sociocultural Factors on Scientific Explanations in Genetics and Ecology Offered by Senior Secondary Students in Lagos State. Ph.D. Thesis, Lagos State University, Ojo, Nigeria, 2019.
44. Okebukola, P.A.O.; Ige, K.; Oyeyemi, A.; Olusesi, O.; Owolabi, O.; Okebukola, F.; Osun, G. Exploring the Impact of Culturo-Techno-Contextual Approach (CTCA) in Tackling Under-Achievement in Difficult Concepts in Biology. In Proceedings of the 2016 Conference of the National Association of Research in Science Teaching (NARST), Baltimore, MD, USA, 14–17 April 2016.
45. Saanu, T. Exploration of the Effect of the Culturo-Techno-Contextual Approach on the Achievement and Attitude of Students in Logic Gate. Master's Thesis, Lagos State University, Ojo, Nigeria, 2015.
46. Adam, U. Potency of Culturo-Techno-Contextual Approach on Students' Achievement in and Attitude Towards Mutation and Variation. Bachelor's Thesis, Lagos State University, Ojo, Nigeria, 2020.
47. Agbanimu, D.O.; Okebukola, P.A.; Oladejo, A.I.; Onowugbeda, F.U.; Peter, E.O.; Awaah, F.; Ademola, I.A.; Gbeleyi, O.A.; Allename, F.A. Flowchart and Algorithm as Difficult Concepts in Computer Studies: Can CTCA Come to the Rescue? In Proceedings of the NARST 95th Annual International Conference: Unity and Inclusion for Global Scientific Literacy: Invite as a Community. Unite as a Community, Vancouver, BC, Canada, 27–30 March 2022.
48. Oladejo, A.I.; Okebukola, P.A.; Akinola, V.O.; Amusa, J.O.; Akintoye, H.; Owolabi, T.; Shabani, J.; Olateju, T.T. Changing the Narratives of Physics-Learning in Secondary Schools: The Role of Culture, Technology, and Locational Context. *Educ. Sci.* **2023**, *13*, 146. [\[CrossRef\]](#)
49. Bervell, B.; Umar, I.N. Utilization decision towards LMS for blended learning in distance education: Modeling the effects of personality factors in exclusivity. *Knowl. Manag. E-Learn. Int. J.* **2018**, *10*, 309–333. [\[CrossRef\]](#)
50. Smith, K.; Hill, J. Defining the nature of blended learning through its depiction in current research. *High. Educ. Res. Dev.* **2019**, *38*, 383–397. [\[CrossRef\]](#)
51. Tekane, R.; Pilcher, L.A.; Potgieter, M. Blended learning in a second-year organic chemistry class: Students' perceptions and preferences of the learning support. *Chem. Educ. Res. Pract.* **2020**, *21*, 24–36. [\[CrossRef\]](#)
52. Zimba, Z.F.; Khosa, P.; Pillay, R. Using blended learning in South African social work education to facilitate student engagement. *Soc. Work Educ.* **2021**, *40*, 263–278. [\[CrossRef\]](#)
53. Fitriyana, N.; Wiyarsi, A.; Ikhsan, J.; Sugiyarto, K.H. Android-Based-Game and Blended Learning in Chemistry: Effect on Students' self-Efficacy and Achievement. *J. Cakrawala Pendidik.* **2020**, *39*, 507–521. [\[CrossRef\]](#)
54. Lane, S.; Hoang, J.G.; Leighton, J.P.; Rissanen, A. Engagement and satisfaction: Mixed-method analysis of blended learning in the sciences. *Can. J. Sci. Math. Technol. Educ.* **2021**, *21*, 100–122. [\[CrossRef\]](#)
55. Vygotsky, L.S. *Thought and Language*; MIT Press: Cambridge, MA, USA, 1962.
56. Moses, A. *Culture, Contexts and Learning*; Marshall Press: New York, NY, USA, 1992.
57. Ausubel, D.P. Reception learning and the rote-meaningful dimension. In *Readings in Educational Psychology*; Routledge: Oxfordshire, UK, 2012; pp. 204–231.
58. Sanni, R.I.; Fakunle, O.I. An Exploration of Classroom Interaction as a Strategy for Improving Students' Achievement in Mathematics. In Proceedings of the LASU 4th International Conference: Education for Global Security, Ojo, Nigeria, 17–20 May 2016.
59. Akpoghol, T.V.; Ezeudu, F.O.; Adzape, J.N.; Otor, E.E. Effects of Lecture Method Supplemented with Music and Computer Animation on Senior Secondary School Students' Academic Achievement in Electrochemistry. *J. Educ. Pract.* **2016**, *7*, 75–86.
60. Agogo, P.O.; Onda, M.O. Identification of students perceived difficult concepts in senior secondary school chemistry in Oju local Government area of Benue State, Nigeria. *Glob. Educ. Res. J.* **2014**, *2*, 44–49.
61. Jaiyeola, E.O. Conducting Qualitative Research Part 1 & 2. YouTube. 2020. Available online: <https://youtu.be/AhNi1EZI39g> (accessed on 8 July 2021).
62. Wilson, L.O. Anderson and Krathwohl-Bloom's Taxonomy Revised. Understanding the New Version of Bloom's Taxonomy. 2016. Available online: <https://pdfslide.net/documents/anderson-and-krathwohl-blooms-taxonomy-revised-anderson-and-krathwohl-blooms.htm> (accessed on 6 November 2020).
63. Okebukola, P.A. 20 Golden Rules for Writing Multiple-Choice Questions. YouTube Channel. 2015. Available online: <https://www.youtube.com/watch?v=ysDZfXPJono> (accessed on 6 November 2020).
64. Oladejo, A.I.; Olateju, T.T.; Okebukola, P.A.; Agboluaje, T.M.; Sanni, R.; Shabani, J.; Akinola, V.O.; Ebisin, A. The convergence of culture, technology and context: A pathway to reducing Mathophobia and improving achievement in mathematics. *Sch. Sci. Math.* **2023**, 1–15. [\[CrossRef\]](#)
65. Okebukola, P.A.; Suwadu, B.; Oladejo, A.; Nyandwi, R.; Ademola, I.; Okorie, H.; Awaah, F. Delivering high school Chemistry during COVID-19 lockdown: Voices from Africa. *J. Chem. Educ.* **2020**, *97*, 3285–3289. [\[CrossRef\]](#)
66. Abd Gani, N.I.; Rathakrishnan, M.; Krishnasamy, H.N. A pilot test for establishing validity and reliability of qualitative interview in the blended learning English proficiency course. *J. Crit. Rev.* **2020**, *7*, 140–143.
67. Akinade, E.A.; Owolabi, O.L. *Research Methods: A Pragmatic Approach for Social Sciences, Behavioural Sciences and Education*; Colonel Publications: Lagos, Nigeria, 2014.
68. Abdulhadi, M.P.; Okebukola, P.A.; Awaah, F.; Oladejo, A.I.; Agbanimu, D. Will CTCA Help Students' Understanding of Difficult Concepts in Computer Studies? In Proceedings of the NARST 95th Annual International Conference: Unity and Inclusion for Global Scientific Literacy: Invite as a Community. Unite as a Community, Vancouver, BC, Canada, 27–30 March 2022.

69. Adeosun, G.; Oladejo, A.I.; Okebukola, P.A. Exploring the Role of Culture on Students' Learning of Difficult Concepts in Biology: CTCA in Action. In Proceedings of the 95th Annual Conference of NARST, Vancouver, BC, Canada, 27–30 March 2022.
70. Akintola, A. Impact of Culturo-Techno-Contextual (CTC) Approach on Students' Achievement on Perceived Difficult Topics in Biology. Bachelor's Thesis, Lagos State University, Ojo, Nigeria, 2019.
71. Vygotsky, L. *Mind in Society: The Development of Higher Psychological Processes*; Harvard University Press: Cambridge, MA, USA, 1978.
72. Ausubel, D. *The Psychology of Meaningful Verbal Learning*; Grune & Stratton: New York, NY, USA, 1963.
73. Pobiner, B.; Watson, W.A.; Beardsley, P.M.; Bertka, C.M. Using human examples to teach evolution to high school students: Increasing understanding and decreasing cognitive biases and misconceptions. In *Evolution Education Re-Considered*; Springer: Cham, Switzerland, 2019; pp. 185–205.
74. Fakoyede, S.J.; Otulaja, F.S. Beads and beadwork as cultural artifacts used in mediating learners' agentic constructs in science classrooms: A case for place-based learning. *Cult. Stud. Sci. Educ.* **2020**, *15*, 193–210. [[CrossRef](#)]
75. Oladejo, A.I.; Olateju, T.; Ogunlade, Y.; Saibu, O.; Agboluaje, T.; Ademola, I.; Ikpah, C.; Okorie, H. Ways to Learning Science are Undergoing Mutation: Would the Culturo-Techno-Contextual Approach be an Effective Variant for Learning Chemistry? *Int. J. Adv. Res.* **2022**, *10*, 640–649. [[CrossRef](#)]
76. Cecilia, O.N.; Bernedette, C.U.; Emmanuel, A.E.; Hope, A.N. Enhancing students' academic performance in Chemistry by using kitchen resources in Ikom, Calabar. *Educ. Res. Rev.* **2020**, *15*, 19–26. [[CrossRef](#)]
77. Alabi, T.O.; Falode, O.C.; Adebambo, M.R.; Abdulkareem, A.Y. The Utilization of YouTube Videos for Instructional Purposes. *Int. J. Educ. Res.* **2020**, *3*, 1–12.
78. Abubakar, H.; Balarabe, S. Self-Report on Lecturers' Perception of YouTube Usage for Academic Purposes in Northwest Geopolitical Zone, Nigeria. *Int. J. Curric. Instr.* **2022**, *14*, 1–23.
79. Koledoye, U.L. Information and Communication Technology Utilization for Skill Acquisition among Adult Distance Learners in Enugu State, Nigeria. *J. Home Econ. Res.* **2021**, *28*, 210.
80. Ogirima, O.A.; Tolulope, J.J.; Temitope, S.J. Future Teachers' Perception towards the Use of YouTube for Teaching-Learning Activities in Nigerian Basic Schools. *Elem. Sch. Forum Mimb. Sekol. Dasar* **2021**, *8*, 81–95. [[CrossRef](#)]
81. Olalere, J.O.; Olatokun, W.M. Does Parenting Style Influence Children's Use of Social Media? Observations from a Faith-based Secondary School, Ibadan, Nigeria. *Libr. Philos. Pract.* **2020**, 1–14.
82. Ono, G.N.; Chiaghana, C.A.; Okeke, A.O. Investigating Information Usefulness of YouTube among Select Unizik Students. *Nnamdi Azikiwe Univ. J. Commun. Media Stud.* **2021**, *2*, 1–14. [[CrossRef](#)]
83. Ajayi, V.O.; Achor, E.E.; Otor, E. Do predict-explain-observe-explain and Vee heuristic strategies have the potentials to eliminate gender difference in students' achievement in organic chemistry? A field report. *BSU J. Sci. Math. Comput. Educ.* **2020**, *1*, 13–21.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.