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Efficacy of Interactive Instructional Strategies on Students' Academic Achievement and Attitude Toward Computer Networking

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ABSTRACT

This study examined the efficacy of interactive instructional strategies in learning computer networking among secondary school students in Lagos State, Nigeria. A quasi-experimental design involving 161 computer students from three purposively selected schools. Two experimental and one control group. The Computer Network Achievement Test and Computer Network Student Attitude Questionnaire were used to collect quantitative data, with reliability indices of .88 and .84, respectively. In contrast, qualitative data were collected using a semi-structured interview guide from five participants in each experimental group. The findings show higher mean performance among students in the experimental group than in the control group. There was also a statistically significant difference in achievement ($F(2, 156) = 378.85$) and attitude ($F(2, 156) = 9.99$), both at $p < .05$, between the experimental and the control groups. This indicates the efficacy of the strategies, thus helping students become active participants in their learning.

Keywords: Interactive instructional strategies, academic achievement, attitude, computer networking, CTCA, graphic organiser

INTRODUCTION

The rapid development and integration of technology have created an interconnected global world in which almost everything can be done regardless of location. In this reality, Information and Communication Technology (ICT) has become an essential component of modern education, equipping learners with the digital skills needed to function effectively in a technology-driven society. Consequently, improving students' learning outcomes in ICT-related subjects has become a priority for educators and researchers (Gbeleyi et al., 2022; Odekeye et al., 2025). These concerns stem from evidence indicating that some students have a poor learning background, while others lack the learning habits necessary to succeed in school (Kruger & Dunning, 1999).

One factor contributing to this challenge is the continued reliance on traditional lecture methods, which often involve largely teacher-led instruction (Onowugbeda et al., 2026; Huang, 2025). Consequently, there is an increasing call for teaching approaches that can enhance students' learning outcomes in both cognitive and psychomotor domains (Olelewe et al., 2020). Computer networking, an important topic in secondary schools' ICT curricula in Nigeria and beyond, helps learners understand abstract concepts such as network topologies, protocols, and data transmission processes (Igboke, 2023). However, its teaching is often hindered by inadequate instructional strategies and limited resources. Empirical evidence supports these concerns. Canning et al. (2018), as cited in Peter et al. (2025), reported that 32% of students experienced difficulties with basic network topology configuration, leading some to avoid or withdraw from computer networking courses. Similarly, Olelewe et al. (2023) reported persistent low achievement in computer networking, attributing it partly to instructional methods.

In response to these challenges, Interactive instructional strategies have been identified as effective approaches for enhancing students' engagement and academic performance (Hodges, 2020; Mosimege & Winnaar, 2021). These strategies promote active participation, collaboration, and meaningful knowledge construction. In particular, the

Culturo-Techno-Contextual Approach (CTCA) integrates learners' cultural experiences with technological content, while Graphic Organisers support the visual structuring of concepts and relationships.

Although previous studies have examined innovative instructional methods in ICT education (Anastasopoulou et al., 2024; **Liu** et al., 2025; Ntorukiri & Riungu, 2021), limited research has investigated the combined effect of CTCA and Graphic Organisers in teaching computer networking at the secondary school level in Nigeria. Therefore, this study examines the effectiveness of these strategies on students' achievement and attitudes toward computer networking. The novelty of this study lies in integrating culturally responsive and visual instructional approaches within a single intervention and in providing empirical evidence of their effectiveness in improving learning outcomes in computer networking among Nigerian secondary school students. To achieve this objective, this study was guided by two specific research questions and a null hypothesis, tested at the $p<0.05$ level of significance.

Research Questions

1. Is there a statistically significant difference in the achievement and attitudes of students taught computer networking using CTCA, graphic organisers, and the lecture method?
2. What are the perceptions of students regarding the culturo-techno-contextual approach (CTCA) and graphics organisers?

Hypothesis

H_{O1}: There is no statistically significant difference in the achievement and attitude of students taught computer networking using CTCA, graphic organisers and the lecture method.

LITERATURE REVIEW

Conceptual Framework of CTCA

The Culturo-Techno-Contextual Approach in this study is an instructional strategy developed by Peter Okebukola and grounded in three multifaceted pedagogical frameworks: cultural relevance, technological integration, and contextually grounded pedagogy (Okebukola, 2020). These pillars are integrated into instructional design to improve students' collaboration, engagement and fairness in learning outcomes (Figure 1). CTCA fosters inclusivity of diverse learning identities, languages and socioeconomic backgrounds of learners (UNESCO, 2017).

Figure 1: *Mechanisms of CTCA (Adopted from Oladejo et al., 2024)*

The cultural aspect of the CTCA involves using indigenous knowledge to represent the learner's culture, thereby providing a better understanding of the concepts. According to Ladson-Billings (1995), teaching with culturally relevant examples connects what students learn in the classroom with their environment while maintaining cultural integrity and intellectual rigour. In computer networking, for example, teachers might use the exchange of farm produce between two farmers after harvest. A farmer who plants plantain may want to exchange with another farmer who planted yams within family members or with someone in the same locality. This shows that there must be a connection between the two farmers before exchange can take place. This illustration can be used to explain the concepts of a Personal Area Network (PAN) and a Local Area Network (LAN), which means there must be a connection between two or more computers before information can be exchanged. The same applies to Metropolitan Area Network (MAN) and Wide Area Network (WAN), meaning farmers will have to connect with other farmers in other villages or localities.

The technological component of CTCA involves intentionally integrating modern tools and media (such as laptops, smartphones, social media, and the internet) to facilitate learning. This inspiration is drawn from **Heidegger** (1977), who claims that technology goes beyond mere tools. It shapes how individuals connect with and understand the world. They are used to significantly support student learning inquiry, collaborative learning and learning beyond school time. Since learners spend so much time with technological devices, they can conduct independent internet searches to support their understanding of the content.

Students now have a deeper appreciation of internet-enabled platforms such as YouTube, Google, and ChatGPT to understand academic content (Hemal et al., 2024). For CTCA, technology serves as an interactive instructional resource for equity and accessibility among students.

The contextual part of CTCA is the learners' immediate learning environment, where the students are located during the teaching and learning process. This aspect allows teachers to use locally relevant examples that students are familiar with to explain the content. Using such examples makes abstract content more meaningful by grounding it in physical objects or events. Contextual examples may include indigenous items, facts, materials from cultural events decades ago, or observable phenomena unrelated to culture, which are used to deepen learners' understanding with clarity (Lin et al., 2007).

Concept of Graphic Organisers

Graphic organisers have their roots in Ausubel's theories and research on advanced organisers. Ausebel (1963) argued that a learner's existing knowledge, which he referred to as cognitive structure, greatly influences their learning. It means learning occurs when new information is incorporated and enriches the existing cognitive structure. To facilitate this process, graphic organisers provide students with a framework for relating existing knowledge to new information (Ausebel, 1963). Prior to 1969, advance organisers had been presented as prose passages. Baron et al. (1969) changed them to tree diagrams that utilised the vocabulary of the concepts to be learned. He called this modification Ausubel's advance organisers "the structured overview", which is a "diagrammatic representation of the basic vocabulary of a unit to show relationships among the concepts represented by those words".

Empirical studies have confirmed the effects of graphic organisers on students' learning outcomes (Odekeye et al., 2023; Robillos, 2023). One advantage of graphic organisers in the classroom is to help students make connections and visualise the relationships between general concepts or topics. In the context of computer networking, graphic organisers are particularly useful for illustrating network structures, explaining the data communication process, and comparing networking concepts. For example, teachers can use flowcharts to show the steps involved in data transmission and tree diagrams to classify network types. Such an illustration is a visual scaffold that can help learners develop mental models of a networking system, which is essential for problem-solving and practical application, thereby strengthening conceptual understanding and supporting learning outcomes and attitudes to learning in computer networks.

Theoretical Framework

This study is guided by two different psychological learning theories: Vygotsky's sociocultural theory (Vygotsky, 1978) and Ausubel's theory of advanced organiser (Ausubel, 1968).

Social Constructivist Learning Theory

The study considered Vygotsky's (1978) Social Constructivist Learning Theory. Social constructivism highlights the role of social and cultural interaction in the learning process. This theory holds that knowledge can be best derived through social interactions (collaborations) among peers and their teacher. This is to say that, according to social constructivist theory, the learner must actively construct their own understanding. Learning occurs when students actively participate in the learning process with the teacher's assistance. A fundamental aspect of Vygotsky's theory is the Zone of Proximal Development (ZPD), the gap between what learners can do independently and what they can achieve with the guidance and support of more skilled others (Vygotsky, 1978). This theory also shows the importance of student-centred approaches and their significant impacts on learning outcomes in computer studies.

Scaffolding is another part of this theory, which provides learners with the appropriate level of support when they are close to mastering it (Vygotsky, 1978). Scaffolding promotes interaction and exchange of academic ideas among peers. This illustrates that students, through collaboration and support, help one another construct knowledge. As with CTCA, the theory can be implemented in the classroom in several ways, allowing students with the content knowledge to be grouped with those without. For instance, if a student struggles with the network topology, that is the arrangement of elements (links, nodes, etc.) of a computer network, a more knowledgeable peer can be allowed to explain the concept, possibly using language that feels more relatable to their peer than the teacher's explanation.

To apply ZPD and scaffolding effectively, teachers must first understand learners' knowledge levels. This thrust reflected CTCA's pre-lesson activities. Without this insight, it becomes difficult to teach the learners with ZPD or provide appropriate support. In line with this theory, ICT instruction should allow students to apply their knowledge beyond the classroom. Consequently, the teacher needs to create opportunities for learners to construct, produce, and use meaningful experiences to help them understand their environment. Through such experiences, students can confidently think, reason, perceive, communicate and reflect on their environment.

Ausubel's Theory of Advance Organisers

David Ausubel was born in 1918 and graduated from the University of Pennsylvania with honours in psychology in 1939. Ausubel's theory of meaningful learning proposed the concept of advance organisers, carefully structured introductory materials presented before teaching to help learners link new knowledge with existing knowledge. According to Ausubel (1968), an advance organiser is appropriately relevant and inclusive materials introduced in advance of learning and presented at a higher level of abstraction, generality, and inclusiveness. Ausubel's theory of learning focuses on the superordinate, representational, and combinatorial processes involved in the reception of information. The central mechanism of learning is subsumption, in which new knowledge is meaningfully connected to relevant ideas already present in the learner's cognitive structure, rather than memorised verbatim. The theory is specifically applicable to reception (expository) learning in formal school contexts. Ausubel distinguished this from rote learning, which lacks meaningful subsumption, and from discovery learning, in which learners must discover information through problem-solving.

This study rested on Ausubel's theory of advanced organisers, as applied through the implementation of CTCA. The first step in implementing CTCA is to inform students ahead of time of the topic to be learned in class and ask each student to reflect on indigenous knowledge or cultural practices and beliefs associated with the topic or concept, making them aware that such reflections are to be shared with others in class when the topic is to be taught (Okebukola, 2020). The teacher provides prior information to students before the lesson; this is an advanced organiser that prepares learners' minds for the new knowledge to be acquired meaningfully. Advance organisers make it easier to learn complex or otherwise difficult structures, provided two conditions are met (Ausubel, 1963). First, learners must actively process and understand the information provided to enhance effectiveness. Second, the knowledge must include the basic content directly related to the new material's concepts. These conditions suggest that, when adapted to pedagogical contexts, advance organisers will effectively enhance learning outcomes.

RESEARCH METHOD

Research Design

This study employed a mixed-methods explanatory sequential design integrating qualitative and quantitative approaches. The qualitative phase employed a quasi-experimental design, with two experimental groups and a control group. This approach utilises intact classes to reflect better the natural educational setting, rather than randomising assignments (Shelley, 2014). Students in the experimental groups were taught using different instructional strategies: CTCA

and graphic organisers, while the control group received instruction through the traditional lecture method. The effectiveness of these approaches was evaluated using a standardised achievement test consistently applied across the three groups.

To ensure equity and fairness among all participants, several measures were considered. First, all students were taught the same content and given equal instructional time irrespective of their specific teaching strategies. Secondly, the researchers ensured that students were assessed under the same conditions using the same standardised achievement test, thereby ruling out extraneous variables and attributing differences in performance to the instructional strategies for learning computer networking. The qualitative phase employed semi-structured interviews to explore students' perceptions of the interactive instructional strategies and to gain an in-depth understanding of the mechanisms through which this intervention influenced their learning experiences. This will also allow the researcher to understand the nuance and complexity of students' experiences with the strategies. (Merriam & Tisdell, 2016).

Sample Size

A sample of 161 senior secondary students offering ICT education from three purposively selected schools in Lagos State, the Western part of Nigeria. Students in their intact classes from the three schools were selected for the control group (n=50; male=26, female=24), while the experimental groups were the CTCA (n=56; male=27; female=29) and the graphic organisers group (n=55; male=29; female=26). (**See Table 1).** These students are in their second year of senior secondary school, which is equivalent to year 12 in the United Kingdom or Grade 11 in the United States. Students who formed the sample had a mean age of 15-17 years.

For the qualitative study, five participants were randomly selected from each experimental group. The selection criteria for the schools were based on the availability of the ICT teacher and ICT laboratories, and on students' access to computers and the internet (particularly during and after school hours). These schools were far apart to prevent inter-group interaction that could have influenced the results.

Table 1: *Participants' demographic information*

Teaching method	Male	Female	Total
Lecture	26	24	50
CTCA	27	29	56
Graphic organisers	29	26	55
Total	82	79	161

Instrumentation

The research team designed a Computer Networking Achievement Test (CNAT) to measure students' academic performance, consisting of 25 multiple-choice questions. Items were drawn from the West African Senior School Certificate Examination (WASSCE) past questions (2014-2024) and the approved computer studies textbooks. The Computer Network Student Attitude Questionnaire (CNSTQ) was the second instrument, consisting of 20 items. The instrument was administered to the groups as a pretest and a posttest, respectively. A semi-structured interview guide (SIG) was used to gather qualitative data on students' perceptions of the implementation of CTCA and graphic organisers.

Validity and reliability of the instruments

CNAT and CNSTQ were subjected to face and content validity. They were validated by respected ICT teachers with significant years of teaching experience in computer studies and ICT education. A test-retest reliability design was used for both instruments, yielding reliability coefficients of 0.88 for CNAT and 0.84 for CNSTQ, analysed using IBM-SPSS version 23. The instruments were piloted with 20 students for the quantitative study, who were not part of the main study population.

Procedure for Data Collection

Data collection began with administering the pre-achievement and pre-attitude tests to all students from the selected schools. The experimental group was taught using CTCA and a graphic organiser, while the control group used the traditional lecture method. The teachers assigned to the experimental groups were trained on the use of these methods for 3 weeks. Teaching lasted for six weeks, with four hours per week for all the groups.

CTCA Classroom Implementation Process

The CTCA followed a five-step process (http://ctcapproach.com) that blends culture, technology, and context into classroom instruction. In the first stage, an interaction was held before the class. Students were introduced to the topic and encouraged to reflect on its cultural aspects, specifically on community beliefs and indigenous knowledge related to computer networks. They are also encouraged to use internet-enabled tools (YouTube) to watch relevant information.

In the second stage, at the beginning of the lesson, students were placed in mixed-ability, mixed-gender groups to discuss their reflections and share their online findings with the class. At the same time, the teacher added relevant cultural insights. The third stage is where the teacher uses contextual examples from the school environment to explain the lesson. In the fourth stage, the teacher addressed and corrected all misconceptions during the discussion. Finally, in the fifth stage,

the teacher sent a brief lesson summary via SMS and WhatsApp, and, from the second stage onward, each group leader has been given most of the responsibilities.

Overall, the CTCA position included interconnected components and teaching steps, making it an effective strategy for enhancing students' understanding of Computer Networks, leading to improved academic performance and a positive attitude toward learning through cultural responsiveness, technology-based support, and context-based teaching.

Graphics Organisers Classroom Implementation Process

The implementation of the graphic organisers in the classroom was designed to follow a 5-step process. In the first stage, the teacher introduces the new topic and activates students' prior knowledge. In the second stage, the teacher provides an example of a concept map of a computer network, illustrating how computers are connected through Wi-Fi or broadband. In the third stage, students identify elements from the concept map that they can observe in their learning environment, such as a WI-FI router. The fourth stage involves students identifying new vocabulary from the concept map and generating definitions through online research. Finally, in the fifth stage, the class compares different definitions created in the mind maps and collaboratively develops a shared set of definitions for key computer network terms.

Traditional Lecture Method Classroom Process

The control group did not receive any specialised treatments; instruction was delivered using the traditional lecture method. This approach was predominantly a teacher-centred approach, characterised by teacher domination. Finally, data collected through semi-structured interviews followed an interview protocol designed to elicit perspectives on interactive instructional strategies. Each interview lasted approximately 10 to 15 minutes, and students were informed about the recording in advance and given the opportunity to review or remove their contributions. This is just to adhere to ethical standards and to respect their opinions.

Methods of Data Analysis

The main aim of this study was to compare the efficacy of interactive instructional strategies on students' academic achievement and attitude toward computer networking. Descriptive statistics were used to analyse quantitative data on students' achievement and attitude scores. The results provided an initial understanding of the distribution of scores and served as a basis for further inferential analysis. For the hypothesis, a Multivariate Analysis of Covariance (MANCOVA) was conducted using IBM SPSS version 23. It was considered appropriate because the study had two different dependent variables: academic achievement and attitude towards computer networking.

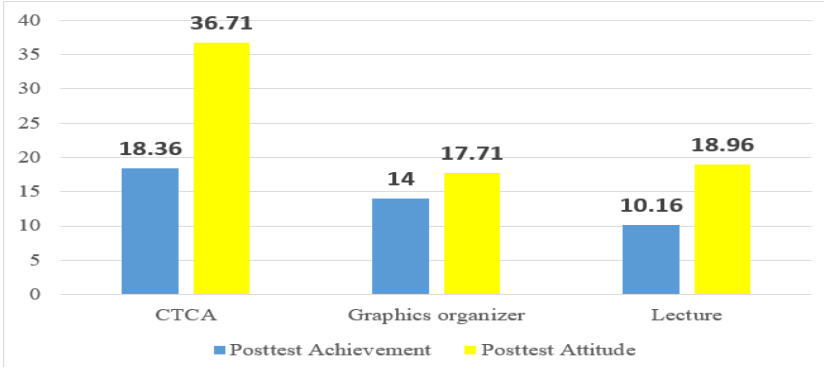
Prior to the main analysis, preliminary assumption tests, including normality, Levene's test, and Box's M test, were conducted to ensure suitability for multivariate analysis, and the results confirmed that the assumptions were met. The pretest scores for achievement and attitude were used as covariates to control initial group differences. The analysis examined the effects of interactive instructional strategies on students' post-test achievement and attitudes simultaneously.

The quantitative data collected through the interview were transcribed and analysed thematically. This involved coding participants' responses to understand their perceptions of the interactive instructional strategies. Themes were developed to capture participants' shared ideas and experiences about how the intervention affected their academic performance and attitudes to learning. The integration of quantitative and qualitative findings helped create a comprehensive understanding of both the intervention's effectiveness and students' experiences with the teaching approach.

RESULTS

In response to research question one, descriptive statistics were applied to the post-test achievement and post-test attitude of students taught using CTCA, graphic organisers, and the lecture method. The analysis indicates that students taught with CTCA had the highest post-test achievement (18.36) and post-attitude (36.71), followed by those taught with the graphic organiser, with post-test achievement (14.00) and post-attitude (17.71), compared to their counterparts in the traditional lecture method, who had the lowest post-test achievement (10.16), but with a higher post-test attitude (18.96) than the graphic organiser group **(See Figure 2)**. These findings underscore the effectiveness of interactive instructional strategies for enhancing students' academic performance in computer networking.

Figure 2: *Mean scores of students in the CTCA, Graphic organisers, and the Lecture method*



To test the hypothesis that there is no statistically significant difference in the achievement and attitudes of students taught computer networking using CTCA, graphic organisers, and the lecture method, a Multivariate Analysis of Covariance (MANCOVA) was conducted. The result showed a statistically significant multivariate effect of teaching strategy on the combined dependent variables (achievement and attitude), with Pillai's Trace = .86 and $F(4, 312) = 58.99$, $p < .05$ **(See Table 2).** This indicates that when the dependent variables were considered together, the approaches produced significant differences among the groups. Since the $p < .05$, the null hypothesis is rejected at the multivariate level. This implies that teaching strategies had a significant overall effect on students' achievement and attitude toward computer networking. Since the MANCOVA revealed a statistically significant multivariate effect of teaching strategy on the combined dependent variable, a follow-up univariate analysis was conducted to determine the specific dependent variables on which the groups differed significantly. From the ANCOVA, the results indicate that the univariate F tests for teaching strategies on achievement ($F(2, 156) = 378.85$) and attitude ($F(2, 156) = 9.99$) were significant ($p < .05$); the null hypothesis was also rejected (**See Table 3).** These results confirmed the efficacy of interactive instructional strategies in enhancing students' performance and attitude in computer networking.

Table 2: *Multivariate Analysis of Covariance (MANCOVA) on the Achievement and Attitude Scores*

Effect	Value	F	Hypothesis df	Error df	Sig
Teaching Strategy: Pillai's trace	.86	58.99	4	312	.000

Table 3: *Analysis of Covariance (ANCOVA) on the Achievement and Attitude Scores with Pretest Achievement and Attitude as Covariates*

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.
Teaching Strategies	Posttest Achievement	1775.87	2	887.93	378.85	.000
Error		365.63	156	2.34		
Teaching Strategies	Posttest Attitude	11662.11	2	5831.05	9.99	.000
Error		91049.27	156	583.65		
Corrected Total	Posttest Achievement	2155.21	160			
	Posttest Attitude	104725.28	160			

The result from the second research question, which sought to determine students' perceptions of the culturo-techno-contextual approach and graphics organisers, was analysed thematically. The findings revealed distinct but complementary perceptions of the CTCA and graphic organisers in learning computer networking. Two major themes emerged: 1. Contextualised understanding through culturally and real-life relevant experiences (CTCA) and 2. Improved conceptual clarity through visual structure (graphic organisers).

Theme 1: CTCA-Contextualised understanding through cultural and real-life relevant experiences

Students reported that CTCA helped them understand abstract computer networking concepts by connecting them to familiar cultural and everyday experiences. The approach's contextual aspect made learning more meaningful and easier to grasp.

Student one: "*When the teacher related computer networking to how phones are connected to each other, even with those abroad without wires, I understood it better*".

Student two: "*Before, computer networking was confusing, but when the example of the town crier was used to explain it, it became clearer*".

These responses indicate that CTCA enhanced conceptual understanding by bridging the gap between theoretical content and students' lived experiences.

Theme 2: Graphic Organisers-Improved conceptual clarity through visual structure

The students in this group indicated that graphic organisers helped them organise and understand complex, networking concepts more effectively. The visual representation of ideas made it easier to follow the lesson content and see the relationship between concepts.

Student one stated: "The use of a diagram made me understand how different parts of a computer network are connected. It made everything clearer".

Student two added: "Using charts and diagrams helped me remember the topics better because I could remember the structure".

These responses suggest that graphic organisers support cognitive organisation and improve understanding through visual learning.

Overall, the findings show that CTCA enhanced students' understanding through cultural and contextual relevance, while graphic organisers improved clarity through visual concepts. Together, these instructional strategies fostered greater engagement, confidence, and a positive perception of computer networking. These qualitative findings complement the quantitative results, providing deeper insights into the effectiveness of the interventions.

DISCUSSION AND CONCLUSIONS

The primary objective of this study was to examine the comparative efficacy of interactive instructional strategies and the traditional lecture method in teaching computer networking to secondary school students. These strategies include the Culturo-Techno-Contextual Approach (CTCA) and graphic organisers, aimed at improving students' academic performance and attitude to learning. The findings revealed that students who were exposed to the interactive instructional strategies, in this study, performed significantly better than their peers in the traditional lecture method, affirming their efficacy for learning outcomes. For post achievement and post-attitude, the results showed that CTCA had higher mean scores than the graphic organiser and the lecture method. This implies that when elements of culture and technology are incorporated into the teaching and learning process, students' understanding of the content will be better and their attitudes toward learning will be enhanced.

This also shows that CTCA not only indicates statistical but also practically significant improvements in students' understanding of computer networking and their attitude toward learning it. These findings are consistent with previous results (Agbanimu et al., 2025; Odekeye et al., 2025), which reported that learner-centred instructional strategies enhance both achievement and learning attitude. Existing studies further support the findings from this study. In computer studies education (Abdulhadi et al. 2023; Ugwuoke et al. 2024), biology (Adam et al. 2024), chemistry (Ademola et al. 2023), and public administration (Awaah et al. 2023). Similarly, drawing on Vygotsky's (1978) sociocultural theory, which highlights that learning is shaped through sociocultural interaction and scaffolding within the Zone of Proximal Development (ZPD). Specifically, our study affirms that cognitive development occurs through culturally grounded supports from teachers, peers, and community contexts. In line with existing studies on the importance of social interaction in learning (Gherghel et al., 2023; Jung et al., 2022), our findings also show that culturally relevant scaffolding significantly improves learning outcomes (Lee & Stephen, 2019; Tzou et al., 2020).

Regarding graphic organisers, the study also found that students taught with this method performed better than those taught through a lecture method. The implication is that graphic organisers create visual displays that help the teacher organise information, making it easier for students to understand. This finding is

consistent with Odekeye et al. (2024), who reported improved performance in computer networking using graphic organisers. It also aligns with Estacio et al. (2022) and Aprianto and Syarifaturrahman (2020), who found that visual representation strategies enhance learners' comprehension of complex content.

The qualitative findings further revealed that interactive instructional strategies enhanced understanding, engagement, and confidence in computer networking. Students reported that contextualised learning helped them connect abstract concepts to real-life experiences, supporting culturally sustaining pedagogy (Paris & Alim, 2014).

In addition, visual representations improved conceptual clarity, while increased confidence and positive attitudes reflected improved self-efficacy and motivation, consistent with Andrade et al. (2022) and Comings (2023). In conclusion, the study provides empirical evidence that interactive instructional strategies, particularly the Culturo-Techno-Contextual Approach (CTCA) and graphic organisers, significantly improve students' academic performance and attitudes toward computer networking. The findings demonstrate that student-centred, culturally grounded, and visually supported instructional approaches promote deeper conceptual understanding, active engagement, and positive learning dispositions in ICT education.

However, the study has some limitations. The use of a quasi-experimental design without full randomisation may introduce selection bias. The sample was limited to three secondary schools in Lagos State, which restricts the generalisability of the findings. Furthermore, the relatively short duration of the intervention may not adequately capture long-term effects on learning outcomes. The qualitative component also involved a small number of participants, which may limit the breadth of perspectives captured. Overall, while the results are promising, they should be interpreted with caution, particularly regarding generalisability and long-term impact. Future studies should consider broader samples, multiple regions, and longitudinal designs to examine sustained effects on achievement, attitudes, retention, and practical ICT skills.

IMPLICATIONS

The findings of this study have several implications for ICT education practice, curriculum design, and educational policy. First, the demonstrated effectiveness of CTCA suggests that teachers should integrate cultural references and real-life contexts into ICT instruction to make abstract concepts more relatable and meaningful to learners. Second, the effectiveness of graphic organisers highlights the importance of visual instructional tools in enhancing comprehension of complex topics such as computer networking. Teachers should therefore be trained in the design and use of structured visual aids to support learning. Third, the study implies that curriculum developers should move beyond traditional lecture-based

approaches and incorporate learner-centred pedagogies that combine cultural relevance and visual representation strategies. This shift can improve students' engagement, understanding, and motivation. Finally, for policymakers, the findings support the need for professional development programmes that equip teachers with skills in culturally responsive pedagogy and instructional design strategies that integrate technology and visual learning tools. This will contribute to improving ICT education outcomes in secondary schools and preparing learners for the demands of a digital society.

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