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Utilization of Digital Tools in Enhancing Environmental Education for Students in Public Secondary Schools of Calabar Municipality, Cross River State, Nigeria

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Abstract

This study investigated the utilization of digital tools in enhancing Environmental Education (EE) for students in public secondary schools of Calabar Municipality, Cross River State, Nigeria. Four research questions and four null hypotheses guided the study. A descriptive survey research design was adopted. The population comprised 2,448 senior secondary two (SS2) students and 86 teachers of environmental-related subjects (Geography, Biology, Agricultural Science, and Civic Education) in the 13 public secondary schools in the municipality. A multi-stage sampling technique was used to select 320 students and all 86 teachers, giving a total sample of 406 respondents. The instrument for data collection was a 32-item structured questionnaire titled "Utilization of Digital Tools in Environmental Education Questionnaire" (UDTEEQ), validated by three experts and pilot-tested. Reliability was established using Cronbach Alpha, yielding an overall coefficient of 0.86. Data were analysed using mean, standard deviation, and independent samples t-test at 0.05 level of significance. Findings revealed that the level of utilization of digital tools in EE is generally low; mobile phones/smartphones, projectors, and basic computers are the most frequently used tools, while interactive simulations, Geographic Information Systems (GIS), virtual reality, and educational mobile applications are rarely used; digital tools significantly enhance students' interest, conceptual understanding, and engagement with environmental issues; and major barriers include inadequate ICT infrastructure, unstable electricity, insufficient teacher training, and high data costs. No significant differences were found in the perceptions of male and female students, or between teachers and students, on the perceived benefits of digital tools. It was recommended, among others, that government and school authorities should equip schools with adequate ICT facilities, provide stable power supply, train teachers in digital pedagogy, and subsidize internet access for educational purposes.

Keywords: Digital tools, environmental education, ICT, secondary schools, Calabar Municipality, sustainability.

Introduction

Environmental Education (EE) has become a global priority in the face of accelerating environmental crises, including climate change, biodiversity loss, deforestation, pollution, and the depletion of natural resources. Conceived at the Tbilisi Intergovernmental Conference of 1977 and reaffirmed by subsequent international declarations, EE is a lifelong, interdisciplinary process designed to develop in learners the awareness, knowledge, attitudes, skills, and commitment necessary to address environmental issues and contribute to sustainable development (UNESCO-UNEP, 1977; UNESCO, 2017). The Sustainable Development Goals, particularly SDG 4.7 and SDG 13, have further entrenched EE as a strategic instrument for achieving environmental sustainability and climate action.

In Nigeria, EE is delivered at the secondary school level through carrier subjects such as Geography, Biology, Agricultural Science, and Civic Education, rather than as a standalone discipline. The National Policy on Education (FRN, 2014) and the Senior Secondary School Curriculum (NERDC, 2013) prescribe environmental content within these subjects, including topics such as ecosystems, pollution, biodiversity, climate change, waste management, soil conservation, and sustainable development. However, the persistent gap between curricular intent and pedagogical practice has limited the effectiveness of EE delivery in many Nigerian secondary schools (Ajiboye & Olatundun, 2010; Nwankwoala, 2015).

Globally, the integration of digital tools into teaching and learning has emerged as a transformative force capable of bridging this gap. Digital tools broadly defined as electronic devices, software applications, online resources, and platforms used to support teaching and learning — include smartphones, computers, tablets, projectors, interactive whiteboards, educational mobile applications, simulation software, virtual reality (VR), augmented reality (AR), Geographic Information Systems (GIS), Google Earth, online videos (such as YouTube), social media, learning management systems (e.g., Moodle, Google Classroom), and a wide range of web-based platforms (UNESCO, 2020; Selwyn, 2016). In the context of EE specifically, digital tools offer unique affordances: they can visualise abstract environmental phenomena, simulate ecological processes, present real-time environmental data, connect learners with environments beyond their immediate locality, and foster active, inquiry-based learning (Reyna et al., 2018).

Despite the recognised potential of digital tools for enhancing EE, available evidence suggests that their utilisation in Nigerian public secondary schools remains low and uneven. Several studies (Adegbenro et al., 2017; Yusuf & Yusuf, 2009; Ajayi & Ekundayo, 2019) have documented inadequate ICT infrastructure, poor electricity supply, insufficient teacher training, and limited internet connectivity as persistent constraints. In Calabar Municipality of Cross River State, casual observations and informal interactions with teachers and students suggest that, while smartphones are nearly ubiquitous among students and many teachers, their educational use in environmental teaching is sporadic and unstructured, and more sophisticated tools such as GIS, simulations, and educational applications are rarely used.

Cross River State, with its rich biodiversity (Cross River National Park, Afi Mountain Wildlife Sanctuary, mangrove ecosystems along the Calabar River, and a tropical rainforest belt), is particularly suited to environmental learning that combines local field experiences with digital exploration of global environmental issues. The capital, Calabar Municipality, hosts most of the state's public secondary schools and is therefore a strategic site for examining how digital tools are currently being used or under-used in environmental education, what benefits are perceived, and what barriers stand in the way. Yet, to the best of the researcher's knowledge, no recent empirical study has comprehensively examined these questions in the municipality. This study therefore investigates the utilization of digital tools in enhancing environmental education for students in public secondary schools of Calabar Municipality.

Environmental challenges facing Cross River State, and Nigeria generally, demand a citizenry that is environmentally literate, ecologically conscious, and equipped with the knowledge and skills to act sustainably. Secondary schools, as institutions that shape adolescents during a critical developmental window, occupy a strategic position in producing such citizens. Environmental content embedded in subjects such as Geography, Biology, Agricultural Science, and Civic Education is intended to fulfil this role.

However, available evidence, including poor performance in environmental questions in WAEC and NECO examinations, low environmental awareness scores in standardised assessments, and observable environmentally degrading behaviours among youths — suggests that EE delivery in Nigerian secondary schools is not achieving its intended outcomes. Conventional chalk-and-talk methods of teaching environmental content, supplemented at best by static textbooks, are widely acknowledged to be inadequate for developing the complex, systems-level thinking that environmental literacy demands.

Digital tools offer a powerful means of overcoming these limitations: simulations can model ecological processes; Google Earth and GIS can bring distant environments into the classroom; educational videos can show real-world environmental phenomena; mobile applications can support data collection in field projects; and social media can connect learners with environmental movements globally. Yet, in Calabar Municipality, the extent to which these tools are being used in environmental teaching is unclear, as are the specific benefits, barriers, and necessary interventions. The persistent gap between the availability of digital technologies (particularly smartphones, which are widely owned even in low-income contexts) and their pedagogical use in EE constitutes a problem requiring empirical investigation. The problem of this study, stated in question form, is: to what extent are digital tools utilised in environmental education in public secondary schools of Calabar Municipality, and how do students, teachers, and the school context shape this utilisation?

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Purpose of the study

The main purpose of this study was to investigate the utilization of digital tools in enhancing environmental education for students in public secondary schools of Calabar Municipality, Cross River State, Nigeria. Specifically, the study sought to:

1. determine the extent to which digital tools are utilised by teachers and students in the teaching and learning of environmental content in public secondary schools in Calabar Municipality;
2. identify the specific digital tools most frequently used in environmental education in the schools;
3. examine the perceived benefits of digital tool utilization on students' learning of environmental education; and
4. ascertain the barriers militating against the effective utilization of digital tools in environmental education in the schools.

Research questions

The following research questions guided the study:

1. To what extent are digital tools utilised in the teaching and learning of environmental education in public secondary schools in Calabar Municipality?
2. Which specific digital tools are most frequently used in environmental education in the schools?
3. What are the perceived benefits of digital tool utilization on students' learning of environmental education?
4. What are the barriers militating against the effective utilization of digital tools in environmental education in the schools?

Hypotheses

The following null hypotheses were formulated and tested at 0.05 level of significance:

HO_1: There is no significant difference between the mean perception of male and female students on the extent of utilization of digital tools in environmental education.

HO_2: There is no significant difference between the mean perception of teachers and students on the specific digital tools most frequently used in environmental education.

HO_3: There is no significant difference between the mean perception of male and female students on the perceived benefits of digital tool utilization.

HO_4: There is no significant difference between the mean perception of teachers and students on the barriers to the effective utilization of digital tools in environmental education.

Literature review

The literature reviewed is organised under four sub-themes: the concept of digital tools and environmental education; the extent and pattern of digital tools utilisation in secondary schools; perceived benefits of digital tools in environmental learning; and barriers to digital tool utilization in Nigerian schools. Digital tools refer to a broad ecosystem of electronic devices, software applications, online platforms, and digital resources used to facilitate teaching, learning, communication, and information processing (Selwyn, 2016; UNESCO, 2020). In educational settings, digital tools encompass hardware such as smartphones, tablets, laptops, desktop computers, projectors, interactive whiteboards, and digital cameras, as well as software and online resources such as word processors, presentation software, search engines, educational videos (e.g., YouTube), simulation and modelling tools (e.g., PhET, NetLogo), Geographic Information Systems (GIS), virtual and augmented reality applications, learning management systems (Moodle, Google Classroom), and a wide range of subject-specific mobile applications.

Environmental Education, on the other hand, is defined by UNESCO (2014) as a learning process that increases people's knowledge and awareness of the environment and associated challenges, develops the necessary skills and expertise to address such challenges, and fosters attitudes, motivations, and commitments to make informed decisions and take responsible action. The integration of digital tools into EE is grounded in constructivist learning theories — particularly Piaget's cognitive constructivism and Vygotsky's social constructivism — which posit that learners actively construct knowledge through interaction with their environment and through socially mediated experiences (Vygotsky, 1978). Digital tools, by enabling interactive, multimodal, and contextually rich experiences, are well aligned with these theoretical orientations.

More recently, the Technological Pedagogical Content Knowledge (TPACK) framework developed by Mishra and Koehler (2006) has provided a useful lens for understanding effective digital integration. According to TPACK, effective use of digital tools in any subject area requires the teacher's integrated knowledge of the content, the pedagogy, and the technology, with attention to the specific affordances and constraints of each. In EE, this implies that the teacher must not only know environmental content and effective pedagogical approaches but also the digital

tools best suited to specific environmental learning objectives.

Empirical studies on the utilisation of digital tools in Nigerian secondary schools have generally reported low to moderate levels of usage, with considerable variation by school location, type, and subject. Yusuf and Yusuf (2009) found that while computers and basic ICT facilities existed in some secondary schools in Nigeria, their pedagogical integration was limited, with most teachers using them primarily for administrative tasks or simply demonstrating computer literacy. Adegbenro et al. (2017) examined Nigerian secondary school teachers' competence in integrating ICT into instruction and found significant gaps in both knowledge and practical skills.

In the specific context of environmental and science teaching, Ajayi and Ekundayo (2019) noted that the use of digital tools in science classrooms in southwestern Nigeria was sporadic, with smartphones being the most widely accessible tool, followed by projectors in better-equipped schools. The use of simulation software, GIS, and immersive technologies like VR/AR was reported as virtually absent. Similar findings have been reported in other parts of sub-Saharan Africa, including studies by Tella et al. (2007) and Mlitwa and Koranteng (2013), which collectively suggest that digital tool utilization in EE-related teaching remains an emerging rather than established practice.

A substantial body of research has documented the benefits of digital tools in environmental and science education. Reyna et al. (2018) reviewed studies on digital media in environmental education and reported consistent gains in student engagement, conceptual understanding, and motivation. Simulations enable students to visualise abstract phenomena such as the carbon cycle, ecological succession, and climate change processes (Rutten et al., 2012). Google Earth and GIS bring distant landscapes into the classroom, allowing learners to explore deforestation, urbanisation, and land-use changes (Bodzin, 2011). Educational videos and documentaries on platforms such as YouTube expose learners to real-world environmental phenomena that they may not encounter directly (Mayer, 2014).

Other documented benefits include the facilitation of collaborative and inquiry-based learning, the development of digital literacy alongside environmental literacy, improved retention of environmental concepts, and the cultivation of pro-environmental attitudes and behaviours (Liu et al., 2017). Importantly, several studies have observed that the affective dimension of EE — students' interest, concern, and willingness to act — appears to be especially enhanced by well-designed digital experiences (Karimzadegan, 2015).

Studies on the constraints to digital tool integration in Nigerian schools have consistently identified a familiar cluster of barriers. Yusuf and Yusuf (2009), Adegbenro et al. (2017), and Ajayi and Ekundayo (2019) have all pointed to inadequate ICT infrastructure (computers, projectors, internet connectivity), unstable electricity supply, insufficient teacher training in digital pedagogy, lack of technical support, the high cost of internet data, and the absence of well-developed policies and funding for ICT integration. School-related factors such as overcrowded classrooms, restrictive policies on student use of mobile phones, and limited time on the timetable also act as barriers (Nwankwoala, 2015). At the system level, the relative neglect of ICT integration in the WAEC/NECO assessment framework reduces the incentive for teachers to make significant pedagogical use of digital tools.

Methodology

Research Design

The study adopted a descriptive survey research design. The design was appropriate because the study sought to describe, through systematic data collection from a representative sample, the existing state of digital tool utilization in environmental education, as perceived by students and teachers (Nworgu, 2015).

Area of the Study

The study was conducted in Calabar Municipality, the capital of Cross River State, Nigeria. Calabar Municipality is one of the eighteen Local Government Areas of the state, located between latitudes 4°55'N and 5°05'N, and longitudes 8°15'E and 8°25'E. The municipality is largely urban, has relatively higher access to electricity and internet services than many other parts of the state, and harbours a significant number of public secondary schools. These features make it a strategic site for investigating digital tool utilization in education.

Population of the Study

The population of the study consisted of all 2,448 senior secondary two (SS2) students offering environmental-related subjects (Geography, Biology, Agricultural Science, and/or Civic Education) and all 86 teachers of these subjects in the 13 public secondary

schools in Calabar Municipality. SS2 students were chosen because they have spent at least one full session studying senior secondary content (and so can speak to teaching practices), are not preoccupied with terminal examinations like SS3 students, and are old enough (typically 15–17 years) to provide informed responses. The figures were obtained from the Cross River State Secondary Education Board.

Sample and Sampling Technique

The sample consisted of 320 students and all 86 teachers, giving a total sample size of 406 respondents. A multi-stage sampling technique was adopted. In the first stage, all 13 public secondary schools in the municipality were included, given the manageable number. In the second stage, proportionate stratified random sampling was used to select students from each school based on enrolment, ensuring representation of both male and female students. In the third stage, all 86 teachers of the four target subjects across the 13 schools were included via census sampling, given their manageable number.

Instrument for Data Collection

The instrument was a researcher-developed structured questionnaire titled "Utilization of Digital Tools in Environmental Education Questionnaire" (UDTEEQ). The questionnaire was divided into two sections. Section A elicited demographic information (status — student or teacher, gender, school, subject taught/offered, age/teaching experience). Section B contained 32 items grouped into four clusters: Cluster I (Extent of Utilization, 7 items); Cluster II (Specific Digital Tools Used, 10 items); Cluster III (Perceived Benefits, 8 items); and Cluster IV (Barriers to Utilization, 7 items). Items in Clusters I and II were rated on a four-point Likert scale (Very Often = 4, Often = 3, Rarely = 2, Never = 1), while items in Clusters III and IV used (Strongly Agree = 4, Agree = 3, Disagree = 2, Strongly Disagree = 1). Two parallel versions of the questionnaire — one for students and one for teachers — were developed, with minor wording adjustments.

Validation of the Instrument

Face and content validation was carried out by three experts: one in Educational Technology, one in Science Education, and one in Measurement and Evaluation, all from the University of Calabar. The experts reviewed the items for clarity, relevance, and adequacy of coverage. Their recommendations, including rephrasing of three ambiguous items, addition of two items on mobile applications and social media, and removal of one redundant item, were incorporated into the final version of the instrument.

Reliability of the Instrument

A pilot test was conducted with 30 respondents (25 students and 5 teachers) from public secondary schools in Calabar South Local Government Area, which is contiguous with the study area but was excluded from the main study. Data from the pilot test were analysed using Cronbach Alpha, yielding an overall reliability coefficient of 0.86. Cluster reliability coefficients were 0.84 (Extent of Utilization), 0.88 (Specific Tools), 0.87 (Perceived Benefits), and 0.85 (Barriers), all of which were considered satisfactory.

Method of Data Collection

The researcher, with the help of four trained research assistants, administered the questionnaire directly to respondents in the 13 selected schools. The instrument was administered during regular school hours, with the permission of school principals and the cooperation of the relevant subject teachers. Out of 406 copies administered, 388 (304 from students and 84 from teachers) were properly completed and returned, giving a return rate of 95.6 per cent. The exercise took five weeks to complete.

Method of Data Analysis

Research questions were answered using mean and standard deviation. A mean of 2.50 and above was interpreted as positive (high utilization, agreement that a tool is used, agreement with a benefit, agreement that a factor is a barrier), and below 2.50 as negative. The hypotheses were tested using independent samples t-test at 0.05 level of significance, with the aid of SPSS Version 25.

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Results

Research Question 1

To what extent are digital tools utilised in the teaching and learning of environmental education in public secondary schools in Calabar Municipality?

Table 1: Mean and Standard Deviation on Extent of Utilization of Digital Tools (N = 388)

S/N	Item Statement	Mean	SD	Remark
1	Digital tools are used in teaching environmental content.	2.18	0.84	Low
2	Teachers use multimedia presentations during EE lessons.	2.05	0.81	Low
3	Students use the internet to research environmental topics.	2.68	0.79	High
4	Educational videos are shown in class on environmental issues.	2.32	0.83	Low
5	Students engage with environmental simulations or apps in school.	1.74	0.72	Low
6	Digital tools are integrated in environmental field projects/assignments.	1.92	0.76	Low
7	Teachers assign online environmental tasks to students.	2.10	0.80	Low
	Cluster Mean	2.14	0.79	Low

Note: Mean ≥ 2.50 = High; Mean < 2.50 = Low.

Table 1 reveals that the overall extent of utilization of digital tools in environmental education is low, with a cluster mean of 2.14 and standard deviation of 0.79. Only one item — students' use of the internet to research environmental topics (mean = 2.68) — fell above the criterion mean, and this is largely a student-initiated activity outside formal classroom instruction. The lowest-rated item was students' engagement with environmental simulations or applications in school (mean = 1.74), suggesting that more advanced digital pedagogies are virtually absent. The implication is that, despite the widespread availability of basic digital devices, their pedagogical integration into EE in public secondary schools in Calabar Municipality remains limited.

Research Question 2

Which specific digital tools are most frequently used in environmental education in the schools?

Table 2: Mean and Standard Deviation on Specific Digital Tools Used (N = 388)

S/N	Digital Tool	Mean	SD	Remark
8	Smartphones/mobile phones (for browsing, videos, apps).	3.18	0.74	High
9	Projectors for classroom presentations.	2.55	0.86	High
10	Basic computers/laptops in the classroom.	2.42	0.88	Low
11	YouTube and other video platforms.	2.78	0.81	High
12	Social media (WhatsApp, Facebook, Twitter/X) for environmental info.	2.84	0.78	High

13	Google Earth/maps for studying landscapes.	1.85	0.79	Low
14	Geographic Information Systems (GIS) software.	1.42	0.66	Low
15	Educational simulations (e.g., PhET).	1.55	0.71	Low
16	Virtual/Augmented Reality applications.	1.32	0.62	Low
17	Subject-specific mobile applications.	1.68	0.74	Low
	Cluster Mean	2.16	0.76	Low

Table 2 shows that smartphones (mean = 3.18), social media platforms (2.84), YouTube and other video platforms (2.78), and projectors (2.55) are the most frequently used digital tools in environmental education in the studied schools. Conversely, more sophisticated tools — Virtual/Augmented Reality (1.32), GIS (1.42), educational simulations (1.55), and subject-specific mobile applications (1.68) — were rarely used. The pattern indicates that digital tool utilization in the municipality is dominated by ubiquitous, personally owned consumer devices rather than dedicated educational technologies, and that the more transformative digital affordances available globally for EE remain largely untapped.

Research Question 3

What are the perceived benefits of digital tool utilization on students' learning of environmental education?

Table 3: Mean and Standard Deviation on Perceived Benefits of Digital Tools (N = 388)

S/N	Perceived Benefit	Mean	SD	Remark
18	Digital tools make environmental topics more interesting and engaging.	3.55	0.58	A
19	Digital tools help students visualise abstract environmental concepts.	3.48	0.61	A
20	They improve students' retention of environmental knowledge.	3.40	0.63	A
21	They expose students to global environmental issues.	3.52	0.60	A
22	They support independent and self-paced learning.	3.38	0.65	A
23	They encourage pro-environmental attitudes and behaviour.	3.30	0.68	A
24	They enhance collaboration among students on environmental projects.	3.32	0.66	A
25	They develop students' digital literacy alongside environmental literacy.	3.45	0.62	A
	Cluster Mean	3.43	0.63	A

Note: A = Agreed (Mean ≥ 2.50); D = Disagreed (Mean < 2.50).

Table 3 shows that respondents strongly agreed that digital tools have multiple benefits for environmental learning, with all eight items above the criterion mean and a cluster mean of 3.43. The most highly rated benefits were that digital tools make environmental topics more interesting and engaging (mean = 3.55) and that they expose students to global environmental issues (mean = 3.52). The findings suggest that — although actual utilization is low (RQ1) — the user community in the study area clearly

recognises the pedagogical value of digital tools, which constitutes a positive precondition for any intervention aimed at increasing their use.

Research Question 4

What are the barriers militating against the effective utilization of digital tools in environmental education in the schools?

Table 4: Mean and Standard Deviation on Barriers to Digital Tool Utilization (N = 388)

S/N	Barrier	Mean	SD	Remark
26	Inadequate ICT infrastructure in schools (computers, projectors, internet).	3.62	0.55	A
27	Unstable electricity supply.	3.68	0.52	A
28	Insufficient training of teachers in digital pedagogy.	3.50	0.59	A
29	High cost of internet data for students and teachers.	3.55	0.57	A
30	Large class sizes that limit individual digital engagement.	3.32	0.66	A
31	School policies restricting student use of mobile phones in class.	3.18	0.72	A
32	Lack of technical support staff in schools.	3.40	0.63	A
	Cluster Mean	3.46	0.61	A

Table 4 shows that respondents agreed that all seven listed barriers militate against the effective utilization of digital tools, with a cluster mean of 3.46. The most pronounced barriers were unstable electricity supply (mean = 3.68), inadequate ICT infrastructure (3.62), high cost of internet data (3.55), and insufficient teacher training in digital pedagogy (3.50). The pattern indicates that the barriers are systemic and interlocking — addressing them effectively will require coordinated interventions across infrastructure, training, and policy domains rather than isolated measures.

Testing of Hypotheses

HO1: There is no significant difference between the mean perception of male and female students on the extent of utilization of digital tools in environmental education.

Table 5: Independent t-test of Male and Female Students on Extent of Digital Tool Utilization

Gender	N	Mean	SD	df	t-cal	p-value
Male	156	2.20	0.78	302	1.12	0.26
Female	148	2.10	0.80			

Significant at $p < 0.05$

Table 5 shows that the calculated t-value of 1.12 with 302 degrees of freedom produced a p-value of 0.26, which is greater than 0.05. The null hypothesis is therefore retained, indicating that male and female students do not differ significantly in their perception of the extent of utilization of digital tools in environmental education.

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HO2: There is no significant difference between the mean perception of teachers and students on the specific digital tools most frequently used in environmental education.

Table 6: Independent t-test of Teachers and Students on Specific Digital Tools Used

Status	N	Mean	SD	Df	t-cal	p-value
Teachers	84	2.22	0.75	386	0.78	0.44
Students	304	2.15	0.77			

Table 6 shows that the calculated t-value of 0.78 (df = 386) yielded a p-value of 0.44, greater than 0.05. The null hypothesis is retained, indicating that teachers and students do not differ significantly in their perception of the specific digital tools most frequently used in EE.

HO3: There is no significant difference between the mean perception of male and female students on the perceived benefits of digital tool utilization.

Table 7: Independent t-test of Male and Female Students on Perceived Benefits

Gender	N	Mean	SD	df	t-cal	p-value
Male	156	3.45	0.61	302	0.65	0.52
Female	148	3.40	0.64			

Table 7 shows that the t-value of 0.65 (df = 302, p = 0.52) is greater than 0.05. The null hypothesis is retained: male and female students do not differ significantly in their perception of the benefits of digital tool utilization in EE.

HO4: There is no significant difference between the mean perception of teachers and students on the barriers to the effective utilization of digital tools in environmental education.

Table 8: Independent t-test of Teachers and Students on Barriers to Digital Tool Utilization

Status	N	Mean	SD	df	t-cal	p-value
Teachers	84	3.52	0.58	386	1.05	0.29
Students	304	3.44	0.62			

Table 8 shows that the calculated t-value of 1.05 (df = 386, p = 0.29) is greater than 0.05. The null hypothesis is retained: teachers and students do not differ significantly in their perception of the barriers to digital tool utilization in EE. In summary, all four null hypotheses were retained at the 0.05 level of significance, indicating a broad consensus among male and female students, and between teachers and students, on the issues investigated.

Discussion of Findings

The findings of this study are discussed under the four research questions, with reference to the existing literature.

The first finding revealed that the overall extent of utilization of digital tools in environmental education in public secondary schools of Calabar Municipality is low (cluster mean = 2.14). Although students reportedly use the internet for environmental research outside class, formal classroom integration of digital tools multimedia presentations, videos, simulations, online assignments, and field projects is sparse. This finding agrees with the work of Yusuf and Yusuf (2009), Adegbenro et al. (2017), and Ajayi and Ekundayo (2019), who consistently reported low to moderate digital tool utilization in Nigerian secondary schools. The implication is that the rich pedagogical potential of digital tools for EE particularly for visualising abstract

concepts and connecting students to global environmental issues remains largely unrealised in the study area.

The second finding showed that smartphones, social media, video platforms (YouTube), and projectors are the most frequently used digital tools, while GIS, virtual/augmented reality, educational simulations, Google Earth, and subject-specific mobile applications are rarely used. This is consistent with the observations of Ajayi and Ekundayo (2019) that consumer-grade, personally owned devices have become the de facto educational technology in many Nigerian schools, while purpose-built educational tools remain largely absent. The dominance of smartphones (mean = 3.18) is consistent with broader Nigerian patterns of mobile phone penetration. The implication is that any intervention to enhance EE through digital tools may achieve quick wins by leveraging existing student devices for structured pedagogical use, while longer-term efforts focus on introducing more sophisticated tools.

The third finding revealed strong agreement on the multiple benefits of digital tools in environmental learning, with a cluster mean of 3.43. Respondents particularly valued the role of digital tools in making environmental topics more engaging, in visualising abstract concepts, in exposing learners to global environmental issues, and in developing digital literacy alongside environmental literacy. These findings corroborate the work of Reyna et al. (2018), Rutten et al. (2012), Bodzin (2011), and Karimzadegan (2015), all of whom documented similar benefits in their studies of digital tools in environmental and science education. The convergence between respondents' perceptions and the international literature is encouraging because it suggests that the user community in the study area would readily welcome enhanced digital integration if structural barriers were addressed.

The fourth finding revealed strong agreement that unstable electricity supply, inadequate ICT infrastructure, high data costs, and insufficient teacher training are the major barriers, with a cluster mean of 3.46. These findings agree closely with prior empirical work in Nigerian schools (Yusuf & Yusuf, 2009; Adegbenro et al., 2017; Ajayi & Ekundayo, 2019; Nwankwoala, 2015) and confirm that the barriers to digital integration in Nigerian education are systemic and interlocking. The particularly high mean for unstable electricity (3.68) is striking given Nigeria's persistent power problems, which severely constrain the use of any electricity-dependent technology in schools. The mean for school policies restricting mobile phone use (3.18), while still indicating agreement, was the lowest among the barriers; this suggests that policy adjustments to allow structured, supervised pedagogical use of student-owned smartphones could be a relatively low-cost lever for change.

Finally, the retention of all four null hypotheses indicates that the perceptions captured in this study converge across gender and across the teacher–student divide. The lack of a gender gap is encouraging from an equity standpoint, and the convergence between teachers' and students' views suggests shared understanding of the realities of digital tool use in EE in the municipality. This consensus provides a stable basis for designing interventions that will be received similarly by both groups.

Conclusion

Based on the findings of this study, it is concluded that the utilization of digital tools in environmental education in public secondary schools of Calabar Municipality is generally low, and that the digital landscape is dominated by personally owned consumer devices (smartphones, social media, video platforms) rather than by educational technologies specifically designed for environmental learning. However, both teachers and students strongly recognise the pedagogical benefits of digital tools for enhancing students' engagement, understanding, and environmental literacy, suggesting that the gap between potential and practice is mainly attributable to structural rather than attitudinal factors. Inadequate ICT infrastructure, unstable electricity supply, high cost of internet data, insufficient teacher training, and restrictive school policies on student mobile phone use constitute the major systemic barriers. Addressing these barriers through coordinated, multi-pronged interventions is necessary if environmental education in the municipality is to harness the full power of digital tools and prepare students for the environmental challenges of the twenty-first century.

Recommendations

Based on the findings and conclusions, the following recommendations are made:

1. The Cross River State Government, through the State Secondary Education Board, should equip all public secondary schools in Calabar Municipality with functional ICT facilities including computer laboratories, projectors, smart boards, and stable internet connectivity

and ensure that these facilities are accessible to teachers and students for environmental and other learning.

2. Government and school authorities should provide stable electricity supply to schools, including alternative sources such as solar power and standby generators where the public grid is unreliable.
3. The Cross River State Universal Basic Education Board (SUBEB) and the Tertiary Education Trust Fund (TETFund), in collaboration with the Faculties of Education in UNICAL and UEEA, should organise regular in-service training and certification programmes for secondary school teachers on digital pedagogy, with specific modules on environmental education applications such as Google Earth, GIS, PhET simulations, virtual field trips, and educational videos.
4. The Federal and State Governments should partner with telecommunications providers to deliver subsidised or zero-rated educational data packages for students and teachers, enabling cost-effective access to online environmental resources.
5. School authorities should review existing policies on mobile phone use and develop structured, supervised frameworks for the pedagogical use of student-owned smartphones during environmental and other lessons, while safeguarding against misuse.
6. The Cross River State Ministry of Education should establish a small unit of trained technical support staff to provide schools in the municipality with ongoing assistance with ICT facilities, maintenance, and troubleshooting.
7. Curriculum planners at NERDC and WAEC/NECO should integrate explicit ICT-based environmental learning outcomes and assessment items in the Geography, Biology, Agricultural Science, and Civic Education curricula to ensure that digital integration is incentivised at the assessment level.
8. Further research should be conducted to evaluate the impact of specific digital tool interventions (GIS modules, virtual field trips, simulation-based instruction) on students' learning outcomes in environmental education in Cross River State and beyond.

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