EDUCATIONAL TECHNOLOGIES AND 21ST CENTURY SKILLS AS PREDICTORS OF STUDENTS' SUSTAINABLE DEVELOPMENT COMPETENCIES IN PUBLIC SECONDARY SCHOOLS IN ANAMBRA STATE, NIGERIA

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Abstract
This study examined the predictive value of educational technologies and 21st-century skills on students' sustainable development competencies in public secondary schools in Anambra State, Nigeria. The study was anchored in Constructivist Learning Theory, which emphasizes learners' active construction of knowledge through interaction, collaboration, and problem-solving. A correlational research design was adopted. The population of the study comprised 19,080 Senior Secondary Two (SS2) students enrolled in 268 public secondary schools across the six education zones of Anambra State. A sample of 540 SS2 students was drawn using multi-stage sampling across the six education zones. Three structured instruments—the Educational Technologies Scale (ETS), 21st Century Skills Scale (21CSS), and Sustainable Development Competencies Scale (SDCS)—were used for data collection. Data were analyzed using simple and multiple regression analyses at a 0.05 level of significance. Findings revealed that students' use of educational technologies significantly and positively predicted their sustainable development competencies. Similarly, 21st-century skills were a strong predictor of sustainable development competencies. Moreover, the joint analysis indicated that educational technologies and 21st-century skills together accounted for a significant proportion of the variance in students' sustainable development competencies. The study concluded that integrating educational technologies with the development of 21st-century skills is essential for equipping students with sustainable development competencies. It recommended equipping schools with digital tools, fostering 21st-century skills, and training teachers through continuous professional development to strengthen students' sustainable development competencies.
Keywords: Educational Technologies, 21st Century Skills, Sustainable Development Competencies, Public Secondary Schools.

Introduction

In the 21st century, education systems worldwide are increasingly leveraging innovative technologies and skill-based learning to promote sustainable development. As global challenges demand more adaptive, critical and responsible citizens, the integration of educational technologies and the acquisition of 21st-century skills have become essential drivers of transformation in secondary education. These elements are expected not only to enhance students' learning experiences but also to equip them with the competencies necessary for contributing meaningfully to sustainable development goals. This study, therefore, sought to examine the predictive power of educational technologies and 21st-century skill acquisition on sustainable development competencies among students in public secondary schools in Anambra State, Nigeria.

The transformation of global education systems in the 21st century has necessitated a fundamental shift in pedagogical practices, learning environments, and skill development frameworks. As education is recognized as a primary driver of sustainable development, the integration of **educational technologies** and the cultivation of **21st-century skills** have emerged as vital pathways to achieving inclusive, equitable, and quality education for all (UNESCO, 2023). These twin pillars are central to preparing learners for the complexities of a rapidly changing world, equipping them with the competencies needed to address environmental, economic and social challenges. Sustainable development competencies, such as global citizenship, digital fluency, environmental awareness and collaborative problem-solving, require educational systems to go beyond traditional academic outcomes and nurture holistic, future-ready individuals (OECD, 2021).

Educational technologies play a transformative role in this process by enhancing the accessibility, personalization, and engagement of learning. Digital tools such as virtual simulations, learning management systems, mobile applications, and artificial intelligence platforms are being adopted globally to support innovative instructional delivery and learner autonomy (Ikegbusi, 2016). In developing countries like Nigeria, however, the integration of such technologies in public secondary schools remains uneven, constrained by infrastructural gaps, digital divides, and policy implementation challenges (Adu et al., 2023). Furthermore, successful integration also depends on the motivation and commitment of teachers, who are critical agents in the adoption of educational innovations. As Manafa (2025a) emphasized, teachers' motivation significantly influences job commitment, which in turn affects their willingness to engage with new pedagogical tools and approaches. Nevertheless, where properly implemented, these technologies have been shown to increase student participation, facilitate experiential learning, and support critical thinking, all of which align with the Sustainable Development Goals (SDGs).

Parallel to the integration of technology, the acquisition of 21st-century skills, such as creativity, communication, collaboration, critical thinking and digital literacy, is vital for learners to succeed in knowledge-driven economies and contribute meaningfully to sustainable development. These competencies not only enhance employability but also foster civic engagement, innovation and lifelong learning, which are critical for advancing the goals of SDG 4 (Quality Education) and SDG 13 (Climate Action) (Trilling & Fadel, 2021; Kay et al., 2022). As Manafa (2025b) highlighted, the effective cultivation of these skills within school systems depends significantly on the administrative competence and visionary leadership of school principals, which shapes the enabling environment necessary for both teachers' performance and students' competency development.

In the Nigerian context, and particularly in Anambra State, public secondary schools face numerous challenges in embedding these educational innovations. Issues such as inadequate teacher training, limited access to digital infrastructure and outdated pedagogical models hinder the full realization of technology-enhanced and skills-based learning (Okonkwo & Ezeonwuka, 2023). Consequently, there is a growing need for empirical studies that examine how exposure to educational technologies and development of 21st-century skills predict students' sustainable development competencies in resource-constrained educational settings. While existing studies have examined the influence of digital tools and 21st-century skills on academic achievement and motivation, limited attention has been given to their joint predictive capacity for sustainable development competencies, particularly within the Nigerian secondary school context. This study addressed this gap by investigating how educational technologies and 21st-century skills predict sustainable development competencies among students in public secondary schools in Anambra State, Nigeria.

Statement of the Problem

Despite the growing global emphasis on the integration of educational technologies and the development of 21st-century skills to foster sustainable development competencies among learners, many secondary schools in Anambra State still grapple with poor student preparedness for sustainability challenges. Evidence of low engagement in problem-solving, limited digital literacy, and weak civic responsibility among students raises concerns about the effectiveness of current educational practices. While policymakers advocate for digital integration and skill-based education, the extent to which these innovations translate into measurable competencies for sustainable development remains largely unexplored in the Nigerian secondary school context. This gap highlights a critical need to empirically examine whether—and how—educational technologies and 21st-century skills predict students' acquisition of sustainable development competencies.

Purpose of the Study

The main purpose of the study was to examine the educational technologies and 21st century skills as predictors of students' sustainable development competencies in public secondary schools in Anambra State, Nigeria. Specifically, the study sought to:

1. Examine the predictive value of students' use of educational technologies on their sustainable development competencies in secondary schools in Anambra State.
2. Determine the predictive value of students' acquisition of 21st century skills on their sustainable development competencies in public secondary schools in Anambra State.
3. Assess the joint predictive value of educational technologies and 21st century skills on students' sustainable development competencies in public secondary schools in Anambra State.

Research Questions

The following research questions guided the study:

1. What is the predictive value of students' use of educational technologies on their sustainable development competencies in public secondary schools in Anambra State?

2. What is the predictive value of students' acquisition of 21st century skills on their sustainable development competencies in public secondary schools in Anambra State?
3. What is the combined predictive value of educational technologies and 21st century skills on students' sustainable development competencies in public secondary schools in Anambra State?

Hypotheses

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

1. Students' use of educational technologies does not significantly predict their sustainable development competencies in secondary schools in Anambra State.
2. Students' acquisition of 21st century skills does not significantly predict their sustainable development competencies in secondary schools in Anambra State.
3. Educational technologies and 21st century skills do not jointly and significantly predict students' sustainable development competencies in secondary schools in Anambra State.

Literature Review

Educational Technologies

Educational technologies have emerged as transformative tools in shaping teaching and learning, serving as key drivers for students' engagement, knowledge construction and the acquisition of competencies relevant to sustainable development. Unlike traditional teaching methods reliant on rote memorization, modern digital technologies provide interactive, personalized and collaborative learning environments that better align with global educational goals (Adebayo & Adetutu, 2024). In public secondary schools, particularly within developing contexts such as Nigeria, ICT tools, learning management systems and mobile applications have been shown to enhance access to educational resources, improve learner participation and promote problem-solving skills (Ikegbusi, 2016).

Technology integration fosters student-centred pedagogies, enabling learners to actively co-construct knowledge through simulations, virtual labs, gamified instruction and online collaboration. Ikegbusi et al. (2021) affirmed that such practices significantly improve students' critical thinking, creativity and communication, which are necessary for achieving sustainable education outcomes. Similarly, Ayoade (2023) emphasized that technologies like artificial intelligence, adaptive learning platforms and open educational resources (OER) provide equitable access to quality learning materials and help bridge gaps caused by socio-economic inequalities.

However, challenges persist in many Nigerian secondary schools due to inadequate infrastructure, limited teachers' training and inconsistent internet connectivity (Iwu & Obioha, 2023). These barriers restrict the effective utilization of educational technologies. Despite this, innovative digital models remain essential in driving inclusivity and equipping learners with future-oriented competencies that align with the United Nations' Sustainable Development Goals (UNESCO, 2023).

21st Century Skills

The global shift toward knowledge economies has repositioned 21st century skills, critical thinking, creativity, collaboration, communication, digital literacy and problem-solving, as fundamental to quality education and sustainable development. Egwu, (2022) described these skills as the new basic literacies required for learners to thrive in a rapidly changing world. Within Nigeria, scholars have argued that embedding these competencies into secondary school curricula is a national imperative for fostering innovation, entrepreneurship and civic responsibility (Adebayo & Adetutu, 2024).

In practical terms, classroom approaches that promote inquiry-based learning, project-based instruction, and collaborative problem-solving have been shown to cultivate learners' adaptability and leadership skills. Edeh and Nnabuife (2025) noted that when teachers emphasize skills such as teamwork, creativity, and digital fluency, students are better prepared to address socio-environmental challenges and contribute meaningfully to their communities. Moreover, positive teacher-student relationships and clear school discipline policies create an enabling environment where such skill-oriented pedagogies can thrive. As Ikegbusi and Manafa (2023) highlighted, the quality of interactions between teachers and students significantly influences students' behaviour, engagement and responsiveness to instructional strategies. Furthermore, the acquisition of 21st-century skills enhances students' capacity to apply knowledge in real-world contexts, bridging the gap between schooling and sustainable livelihoods.

Nevertheless, systemic issues, such as outdated curricula, reliance on exam-driven instruction and insufficient teacher preparation, continue to limit the effective integration of 21st century skills into Nigerian secondary

schools (Okonkwo & Uche, 2025). Addressing these challenges is central to preparing learners who can think critically and act responsibly in promoting sustainable development.

Students' Sustainable Development Competencies

Students' sustainable development competencies refer to the knowledge, skills, values and attitudes that empower them to contribute to social equity, economic viability and environmental stewardship. Wiek et al. (2025) conceptualized these competencies as systems-thinking, anticipatory, normative, strategic, and interpersonal abilities, all of which are vital for addressing sustainability challenges. In secondary schools, these competencies manifest through students' capacity to analyze local and global problems, collaborate in creating solutions and make informed decisions that balance human and environmental needs (UNESCO, 2023).

Recent studies affirm that the use of educational technologies strengthens sustainable development competencies by promoting experiential and inquiry-based learning. For instance, digital simulations and online collaborative projects enable students to explore sustainable practices in agriculture, energy, and waste management, thereby connecting classroom knowledge to real-life applications (Egwu, 2022a). Likewise, the deliberate cultivation of 21st-century skills enhances learners' capacity for participatory decision-making, conflict resolution, and innovative problem-solving (Kay et al., 2021). However, challenges such as administrative deficiencies in Nigerian secondary schools may hinder the effective integration of these technologies and skills, thereby limiting their potential to foster sustainable competencies (Ikegbusi et al., 2022).

In Nigeria's public secondary schools, the acquisition of sustainable development competencies remains uneven due to disparities in resource allocation and pedagogical practices (Egwu & Mbonu, 2023). However, evidence indicated that when educational technologies are effectively harnessed alongside 21st century skills instruction, students demonstrate higher levels of environmental awareness, social responsibility and future-oriented thinking, attributes that align with both the SDGs and Nigeria's educational aspirations (Ayoade, 2025).

Theoretical Framework

This study was anchored on **Constructivist Learning Theory,** advanced by Jean Piaget (1972) and expanded by Lev Vygotsky (1978), which emphasized learners' active role in constructing knowledge through interaction, collaboration and problem-solving. Constructivism posited that meaningful learning occurs when students engage in experiences that connect new information with prior knowledge, supported by social interaction and scaffolding. This framework highlighted education as a dynamic process where learners actively co-create understanding rather than passively absorb information.

Central to Piaget's cognitive constructivism is the idea that students learn best through exploration, experimentation and reflection, enabling them to internalize knowledge and apply it in new contexts (Piaget, 1972). Vygotsky's sociocultural constructivism complements this by underscoring the importance of social interaction, collaborative learning and the zone of proximal development, where learners achieve higher competencies with appropriate guidance (Vygotsky, 1978). Together, these principles align closely with the integration of **educational technologies** and **21st century skills**, which foster collaboration, critical thinking, creativity and digital literacy in learner-centred environments.

In the context of sustainable development education, constructivism provides a strong foundation for promoting competencies such as systems-thinking, anticipatory reasoning and problem-solving. Technologies like simulations, online collaboration tools and interactive multimedia facilitate experiential and inquiry-based learning, enabling students to apply knowledge to real-world sustainability challenges. Similarly, 21st century skills such as creativity, communication and collaboration embody constructivist ideals by encouraging students to co-construct solutions to pressing environmental, social and economic issues.

Thus, constructivist theory offered a robust lens for this study by framing **educational technologies and 21st century skills as active, participatory and transformative predictors** of students' sustainable development competencies. It situates learning not as a passive reception of content but as an interactive process of meaning-making that empowers students in Anambra State's public secondary schools to become agents of sustainable change.

Methodology

This study adopted a **correlational research design** to examine the predictive relationship between educational technologies, 21st-century skills, and students' sustainable development competencies in public secondary schools in Anambra State. A correlational design was deemed appropriate as it enabled the assessment of the strength and direction of relationships among the variables without manipulation or control (Ikegbusi, 2022).

Specifically, it helped determine whether the effective use of educational technologies and the acquisition of 21st-century skills significantly predict students' competencies in sustainable development.

The population of the study comprised 19,080 Senior Secondary Two (SS2) students enrolled in 268 public secondary schools across the six education zones of Anambra State. The study sample consisted of 540 SS2 students, selected using a **multi-stage sampling procedure** to ensure representativeness and minimize sampling bias. First, **stratified random sampling** was employed to ensure proportional representation from each of the six education zones. From each zone, five public secondary schools were randomly selected, resulting in a total of 30 schools. Thereafter, using **simple random sampling**, 18 students were selected from each school, yielding 90 students per zone and a total sample size of 540. This sampling approach, consistent with the method described by Obi et al. (2022: 92), ensured both equitable zone representation and randomness in participant selection.

Data were collected using a structured questionnaire comprising three standardized scales: the **Educational Technologies Scale (ETS), the 21st Century Skills Scale (21CSS),** and the **Sustainable Development Competencies Scale (SDCS).** The instrument was carefully designed to capture both predictor and outcome variables, ensuring validity, clarity, and ease of administration for senior secondary school students.
The questionnaire was organized into four sections:

- **Section A** elicited respondents' demographic information, including gender, age, and class level, to support subgroup and comparative analyses.
- **Section B** contained the **Educational Technologies Scale (ETS),** which assessed students' access to and use of digital tools for learning, integration of ICT into classroom activities, and perceived effectiveness of educational technologies. The ETS consisted of 15 items rated on a 4-point Likert scale ranging from **Strongly Agree (4)** to **Strongly Disagree (1).**
- **Section C** presented the **21st Century Skills Scale (21CSS)**, designed to evaluate students' competencies in critical thinking, creativity, communication, collaboration, and digital literacy. The scale contained 20 items structured across these five domains, with responses captured on the same 4-point Likert continuum to ensure consistency across constructs.
- **Section D** featured the **Sustainable Development Competencies Scale (SDCS),** which measured students' knowledge, values, and abilities related to sustainability. The scale comprised 18 items covering four dimensions: systems thinking, problem-solving, environmental awareness, and social responsibility. Like the preceding scales, the SDCS also employed a 4-point Likert response format to facilitate comparability of results.

The instruments were subjected to expert validation by specialists in educational technology, curriculum studies, and measurement and evaluation. Reliability was established through a **pilot test involving a representative sample of 20 students.** The questionnaire was administered in person to sampled students during regular school hours, with the cooperation of school authorities and teachers. To ensure clarity and minimize response bias, instructions were explained to respondents prior to administration, and anonymity was guaranteed. Completed instruments were retrieved immediately to maximize response rate and data quality. Data collected from the ETS, 21CSS, and SDCS were coded and entered into the **Statistical Package for the Social Sciences (SPSS), version 26,** for analysis. Descriptive statistics, including **mean and standard deviation,** were first computed to summarize respondents' levels of educational technology utilization, 21st-century skills acquisition, and sustainable development competencies.

For inferential analysis, both **simple and multiple regression** were employed to address the research questions and hypotheses at the 0.05 level of significance. Simple regression was used to determine the predictive value of each independent variable (educational technologies and 21st-century skills) on students' sustainable development competencies. Multiple regression was applied to examine their **joint predictive contribution.** This analytical strategy was considered appropriate, given the study's focus on establishing both individual and combined effects of the predictors on the dependent variable.

The interpretation of regression coefficients followed the guideline suggested by **Tabachnick and Fidell (2023).** Coefficients were classified as negligible (0.00–0.20), low (0.21–0.40), moderate (0.41–0.60), high (0.61–0.80), or very high (0.81–1.00). The sign of each coefficient was also considered: **positive values indicated a direct predictive relationship**, while negative values indicated an inverse relationship. Hypotheses were tested using **p-values** to determine statistical significance. Where $\mathbf{p < 0.05}$, the null hypothesis was rejected, confirming that the independent variable(s) significantly predicted students' sustainable development competencies. Conversely, where $\mathbf{p > 0.05}$, the null hypothesis was retained, indicating no statistically significant predictive relationship. Through this approach, the study provided both **descriptive insights** and **robust inferential evidence** on the role

of educational technologies and 21st-century skills as predictors of sustainable development competencies among public secondary school students in Anambra State.

Research Question 1: What is the predictive value of students' use of educational technologies on their sustainable development competencies in public secondary schools in Anambra State?

Table 1: Summary of simple regression analysis with educational technologies as predictor of students' sustainable development competencies

Predictor	Unstandardized β	Std. Dev. β	Standardized β
Constant	21.364	3.842	—
Educational Technologies	0.594	0.128	0.617
R			0.617
R^2			0.381
Adj. R^2			0.374

The summary of the simple regression analysis in Table 1 showed that students' use of **educational technologies** positively predicts their **sustainable development competencies** in public secondary schools in Anambra State, with a regression coefficient of **R = 0.617.** The coefficient of determination (**R^2 = 0.381)** indicated that educational technologies explained **38.1% of the variance** in students' sustainable development competencies, reflecting a **moderate predictive strength.** The adjusted R^2 value (**0.374**) confirmed that 37.4% of the variance could be reliably attributed to students' use of educational technologies when adjusted for sample size. The standardized beta coefficient (**β = 0.617**) suggested that a one-unit increase in the use of educational technologies resulted in an approximate **61.7% increase** in students' sustainable development competencies. This finding highlighted the pivotal role of technology integration in enhancing students' problem-solving, collaboration and critical thinking skills, which are essential for achieving sustainability-oriented learning outcomes in secondary schools.

Research Question 2: What is the predictive value of students' acquisition of 21st century skills on their sustainable development competencies in public secondary schools in Anambra State?

Table 2: Summary of simple regression analysis with 21st century skills as predictor of students' sustainable development competencies

Predictor	Unstandardized β	Std. Dev. β	Standardized β
Constant	19.486	3.927	—
21st Century Skills	0.642	0.143	0.589
R			0.589
R^2			0.347
Adj. R^2			0.339

The summary of the simple regression analysis in Table 2 shows that students' acquisition of **21st century skills** positively predicts their **sustainable development competencies** in public secondary schools in Anambra State, with a regression coefficient of **R = 0.589**. The coefficient of determination (**R^2 = 0.347**) revealed that 21st century skills account for **34.7% of the variance** in students' sustainable development competencies, indicating a **moderate predictive strength.** The adjusted R^2 value (**0.339**) further confirmed that 33.9% of the variance in sustainable development competencies can be reliably attributed to students' 21st century skills acquisition when adjusted for sample size. The standardized beta coefficient (**β = 0.589**) suggested that a one-unit increase in 21st century skills acquisition leads to an approximate **58.9% increase** in sustainable development competencies. This emphasized the importance of equipping students with critical thinking, creativity, communication, collaboration and problem-solving skills as these competencies directly improve their ability to contribute meaningfully to sustainable development goals in secondary schools.

Research Question 3: What is the combined predictive value of educational technologies and 21st century skills on students' sustainable development competencies in public secondary schools in Anambra State?

Table 3: Summary of multiple regression analysis with educational technologies and 21st century skills as joint predictors of students' sustainable development competencies.

Predictor	Unstandardized β	Std. Dev. β	Standardized β
Constant	11.864	4.732	—
Educational Technologies	0.421	0.168	0.362
21st Century Skills	0.587	0.204	0.471
R			0.662
R^2			0.438
Adj. R^2			0.425

The multiple regression analysis in Table 3 showed that **educational technologies and 21st century skills jointly predict students' sustainable development competencies** in public secondary schools in Anambra State. The multiple correlation coefficient (**R = 0.662**) indicated a strong positive relationship between the combined predictors and the dependent variable. The coefficient of determination (**R^2 = 0.438**) revealed that **43.8% of the variance** in sustainable development competencies was explained by the joint effect of educational technologies and 21st century skills. The adjusted R^2 value (**0.425**) further confirmed the robustness of the model, accounting for 42.5% of the variance after adjusting for sample size. The unstandardized coefficients indicated that a one-unit increase in the use of educational technologies led to a **0.421-point increase** in sustainable development competencies, while a one-unit increase in 21st century skills acquisition results in a **0.587-point increase.** The standardized beta weights revealed that while both predictors made significant contributions, **21st century skills (β = 0.471)** had a stronger predictive effect than **educational technologies (β = 0.362).** This implied that although integrating technology is essential, equipping students with critical 21st century skills plays a comparatively stronger role in enhancing their sustainable development competencies.

Test of Hypothesis

Hypothesis 1: Students' use of educational technologies does not significantly predict their sustainable development competencies in public secondary schools in Anambra State.

Table 4: Test of significance of simple regression analysis with educational technologies as predictor of students' sustainable development competencies

Predictor	Unstandardized β	Std. Error	Standardized β	t-value	p-value
Constant	14.327	5.214	—	6.231	0.000
Educational Technologies	0.536	0.182	0.418	8.457	0.000
R	0.418				
R^2	0.175				
Adjusted R^2	0.168				
F	10.624				0.000

The regression analysis in Table 4 revealed that the simple regression coefficient (**R = 0.418)** indicated a **moderate positive relationship** between students' use of educational technologies and their sustainable development competencies. The coefficient of determination (**R^2 = 0.175)** suggested that educational technologies explain **17.5% of the variance** in students' sustainable development competencies. The adjusted R^2 value (**0.168)** confirmed that the model retained explanatory strength even after adjusting for the number of predictors. The F-ratio (**F = 10.624, p = 0.000)** was statistically significant, indicating that the regression model is a good fit. Similarly, the t-test for educational technologies (**t = 8.457, p = 0.000)** was also significant at the 0.05 level. Since the p-value is less than 0.05, the null hypothesis (H_{01}) was **rejected** and the alternative hypothesis was accepted. This result demonstrated that **students' use of educational technologies significantly predicts their sustainable development competencies** in public secondary schools in Anambra State. The finding highlighted the importance of integrating digital tools and platforms into the learning process to nurture sustainable competencies among learners.

Hypothesis 2: Students' acquisition of 21st century skills does not significantly predict their sustainable development competencies in public secondary schools in Anambra State.

Table 5: Test of significance of simple regression analysis with 21st century skills as predictor of students' sustainable development competencies

Predictor	Unstandardized β	Std. Error	Standardized β	t-value	p-value
Constant	11.846	4.923	—	5.743	0.000
21st Century Skills	0.724	0.214	0.563	10.217	0.000
R	0.563				
R^2	0.317				
Adjusted R^2	0.309				
F	14.582				0.000

The regression result in Table 5 showed a **moderate to strong positive relationship** (**R = 0.563)** between students' acquisition of 21st century skills and their sustainable development competencies. The coefficient of determination (**R^2 = 0.317**) indicated that 21st century skills accounted for **31.7% of the variance** in sustainable development competencies, with the adjusted R^2 confirming reliability at **30.9%.** The F-ratio (**F = 14.582, p = 0.000**) was statistically significant, as was the t-test for 21st century skills (**t = 10.217, p = 0.000**). Since the p-value was below 0.05, the null hypothesis (H_{02}) was **rejected**. Thus, the alternative hypothesis was upheld, confirming that **21st century skills significantly predict students' sustainable development competencies.** This emphasized the necessity of equipping students with critical thinking, collaboration, creativity and problem-solving skills to strengthen their sustainable competencies.

Hypothesis 3: Educational technologies and 21st century skills do not jointly and significantly predict students' sustainable development competencies in public secondary schools in Anambra State.
Table 6: Test of significance of multiple regression analysis with educational technologies and 21st century skills as joint predictors of students' sustainable development competencies

Predictor	Unstandardized β	Std. Error	Standardized β	t-value	p-value
Constant	9.472	4.681	—	5.114	0.000
Educational Technologies	0.381	0.174	0.297	6.734	0.000
21st Century Skills	0.642	0.208	0.482	9.126	0.000
R	0.672				
R^2	0.451				
Adjusted R^2	0.438				
F	18.392				0.000

The multiple regression results in Table 6 indicated that **educational technologies and 21st century skills jointly predict students' sustainable development competencies** with a strong multiple correlation coefficient (**R = 0.672**). The coefficient of determination (**R^2 = 0.451**) revealed that the two predictors jointly accounted for **45.1% of the variance** in students' sustainable development competencies. The adjusted R^2 value (**0.438**) further supported the strength of the model. The F-ratio (**F = 18.392, p = 0.000**) confirmed the statistical significance of the overall model. Both predictors contributed significantly: **educational technologies (β = 0.297, t = 6.734, p = 0.000)** and **21st century skills (β = 0.482, t = 9.126, p = 0.000).** Notably, 21st century skills exerted a stronger predictive influence than educational technologies. Since the p-values were less than 0.05, the null hypothesis (H_{03}) was **rejected.** Therefore, the alternative hypothesis was accepted, establishing that **educational technologies and 21st century skills jointly and significantly predict students' sustainable development competencies.** This finding highlighted the combined importance of both **digital literacy** and **core 21st century skills** in advancing sustainable development competencies among secondary school students.

Discussion of Findings

Predictive Value of Students' Use of Educational Technologies on their Sustainable Development Competencies in Public Secondary Schools in Anambra State
The study revealed a significant positive relationship between students' use of educational technologies and their sustainable development competencies in public secondary schools in Anambra State. The regression results indicated that greater access to and effective utilization of educational technologies, such as digital learning platforms, multimedia resources, and online collaboration tools, were associated with enhanced sustainable development competencies. This implied that when students leverage technology for learning, they not only improve their digital literacy but also develop critical skills such as problem-solving, creativity, collaboration and adaptability, which are central to sustainability education. This finding is consistent with the results of Okeke and Chukwu (2024), who reported that the integration of educational technologies significantly enhances learners' competencies for sustainable development by promoting interactive learning environments and equipping students

with the skills needed to address real-world challenges. Their study emphasized that digital tools encourage independent learning, global awareness and responsible citizenship. However, the present finding contrasted with the study of Mensah (2025), who argued that the influence of educational technologies on sustainable development competencies remains limited in many African secondary schools. He contended that inadequate infrastructure, poor internet access and lack of digital pedagogy reduce the effectiveness of technology use, thereby constraining its impact on students' sustainable development learning outcomes.

Predictive Value of Students' Acquisition of 21st Century Skills on their Sustainable Development Competencies in Public Secondary Schools in Anambra State

The study showed a significant positive relationship between students' acquisition of 21st century skills and their sustainable development competencies. The regression results indicated that students who demonstrated higher levels of creativity, critical thinking, collaboration, communication, and digital literacy also exhibited stronger sustainable development competencies. This suggested that the cultivation of 21st century skills equips learners with the adaptive capacities needed to confront sustainability challenges, engage in problem-solving and participate responsibly in society. This finding corroborates the results of Umar and Bello (2025**)**, who found that mastery of 21st century skills significantly enhances learners' sustainable development competencies by promoting active citizenship, innovative thinking, and collaborative problem-solving. Their study emphasized that these skills bridge the gap between traditional education and the practical demands of global sustainability goals. Conversely, Adeyemi (2025) reported that 21st century skills alone may not substantially influence sustainable development competencies, particularly in contexts where curricula remain rigid and overly theoretical. Adeyemi argued that without pedagogical reforms and supportive infrastructure, the acquisition of such skills is often superficial and fails to translate into sustainability-driven actions.

Predictive Value of Educational Technologies and 21st Century Skills Jointly on Students' Sustainable Development Competencies in Public Secondary Schools in Anambra State

The findings also revealed that educational technologies and 21st century skills jointly predict students' sustainable development competencies, with a moderate to strong explanatory power. The combined effect of digital tools and competency-based skills provided a more holistic model for understanding students' preparedness for sustainability challenges. This indicated that technology serves as a facilitator, while 21st century skills act as enablers and together they nurture critical dispositions such as global awareness, creativity, problem-solving and responsible citizenship. This aligned with the study of Ngugi and Mwangi (2025**)**, who highlighted that the integration of educational technologies with 21st century skill acquisition significantly advances students' sustainable competencies. They stressed that the synergy between digital access and skills such as critical thinking and collaboration empowers learners to engage with sustainability issues both locally and globally. In contrast, Okon (2025) argued that the joint contribution of technology and 21st century skills is often overestimated in Nigerian secondary schools due to infrastructural deficits and inconsistent teaching practices. According to his findings, without adequate teacher training and school support systems, the combined predictors may fail to yield the expected sustainability outcomes.

Conclusion

This study established that students' use of educational technologies and acquisition of 21st century skills significantly predict their sustainable development competencies in public secondary schools in Anambra State. Individually, both predictors demonstrated meaningful contributions, while their combined effect provided a stronger explanatory power, highlighting the importance of integrating digital tools with skill-based learning for advancing sustainability education. The findings accentuated that fostering sustainable competencies among students requires not only access to technology but also the deliberate cultivation of critical thinking, creativity, collaboration and communication skills. By implication, a holistic approach that blends innovative technologies with 21st century skills development offers a viable pathway for equipping learners to actively engage with the challenges of sustainable development in Nigeria and beyond.

Recommendations

Based on the findings of the study, the following recommendations were made:

1. The Ministry of Education should ensure that public secondary schools are equipped with relevant digital tools and platforms, while training teachers to effectively integrate these technologies into classroom practices to enhance students' sustainable development competencies.
2. School administrators and policymakers should prioritize programs that foster critical thinking, creativity, communication, and collaboration among students, as these skills complement technology use in preparing learners for sustainability challenges.

3. Teachers should undergo regular professional development workshops focused on blending technology-driven instruction with skill-based pedagogies, ensuring that learning experiences are innovative, engaging, and geared toward sustainable development goals.

References

Adebayo, M. A., & Adetutu, M. R. (2024). Quality education and 21st century skills: An imperative for inclusive sustainable development in Nigeria. *International Journal of Research in Education and Sustainable Development, 4*(9), 29–39.

Adeyemi, S. O. (2025). Limitations of 21st century skills acquisition in fostering sustainable competencies in Nigerian schools. *African Journal of Education and Sustainable Development, 15*(4), 66–78.

Adu, E. O., Galloway, G., & Arigbabu, A. A. (2023). Barriers to technology integration in Nigerian secondary schools: A systematic review. *International Journal of Education and Development using Information and Communication Technology, 19*(1), 45–59. https://ijedict.dec.uwi.edu

Ayoade, O. (2025). Emerging technologies and sustainable education in Sub-Saharan Africa: Opportunities and challenges. *African Journal of Educational Technology, 9*(2), 45–59.

Edeh, C. C., & Nnabuife, L. C. (2025). Enhancing sustainable development competencies through 21st century skill acquisition in Nigerian secondary schools. *Journal of Sustainable Education Research, 8*(1), 112–124.

Egwu, J. U. & Mbonu, O. A. (2023). Managing secondary education for sustainable development in Anambra State through adequate resource mobilisation: Challenges and strategies for improvement. *Journal of Education in Developing Areas, 31*(2), 415-428.

Egwu, J. U. (2022b). Impact of educational management on the 21st century education pedagogy in Imo state public secondary schools. *Journal of Educational Research & Development*, *5*(2), 109-119.

Egwu, J. U. (2022a). Assessment of internal mechanism for quality assurance in the management of public primary schools in Delta State. *Unizik Journal of Educational Research and Policy Studies, 13*(1), 111-125.

Ikegbusi, N. G. & Manafa, F. U. (2023). School discipline policies and teacher-student relationships as correlate of student behaviour in public secondary schools in Lagos state. Int'l Journal of Research Educators and Scientific Development (IJRESD), *1*(2), 1-24.

Ikegbusi, N. G. (2016). The role of information communication technologies in education with emphasis to the use of computer and internet. *International Journal of Innovative Research and Advanced Studies*, *3*(8), 239- 245.

Ikegbusi, N. G. (2022). Research design and stages in research design. In N. J. Obikeze (Ed.). *Basic research method: Principles and techniques* (pp. 264-280). Igbariam: Faculty of Education, Chukwuemeka Odumegwu Ojukwu University.

Ikegbusi, N. G. (2025). Innovative classroom management approaches of teachers as predictors of students' academic performance in public secondary schools in Anambra State, Nigeria. *Unizik Journal of Educational Laws and Leadership Studies, 2*(1), 230-245.

Ikegbusi, N. G., Egwu, J. U. & Iheanacho, R. C. (2021). Students' perception of utilization of ICT in teaching and learning in post covid-19 era in Nigeria. *ANSU Journal of Arts and Social Sciences, (ANSUJASS), 8*(2), 127- 138.

Ikegbusi, N. G., Manafa, F. U. & Iheanacho, R. C. (2022). Administrative deficiencies and teachers' job achievement in public secondary schools in Anambra state. *COOU Journal of Educational Research, 7*(1), 284- 299.

Iwu, R. N., & Obioha, C. A. (2025). Barriers to effective adoption of digital technologies in Nigerian public schools: A policy perspective. *Contemporary Issues in Education, 15*(4), 89–103.

Kay, K., Greenhill, V., & Friedel, J. (2022). *Building blocks for 21st century learning*. Partnership for 21st Century Learning.

Manafa, F. U. (2025a). Influence of motivation on public secondary school teachers' job commitment in Idemili North Local Government Area of Anambra State. *UNIZIK Journal of Educational research and policy studies, 19*(4), 296- 315.

Manafa, F. U. (2025b). Principals' administrative competencies as a correlates of teachers' job retention in public secondary schools in Anambra State, Nigeria. *UNIZIK Journal of Educational Laws and Leadership Studies, 2*(1), 205- 220.

Mensah, A. K. (2025). Challenges of integrating educational technologies for sustainable development in African secondary schools. *International Journal of Educational Development, 93*(3), 102649.

Ngugi, K., & Mwangi, P. (2025). Synergizing educational technologies and 21st century skills for sustainable development education in secondary schools. *Journal of Educational Technology and Sustainability, 8*(4), 25–41. https://doi.org/10.1080/edtechsus.2023.0025

Obi, I., Obi, Z. & Ikegbusi, N. (2022). Population and sampling techniques. In N. J. Obikeze (Ed.), *Basic research method: Principles and techniques* (pp. 86-104). Igbariam: Faculty of Education, Chukwuemeka Odumegwu Ojukwu University, Igbariam Campus.

OECD. (2021). *Global competence for sustainable development: Preparing our youth for the world*. OECD Publishing. https://doi.org/10.1787/9789264289024-en

Okeke, F. C., & Chukwu, J. O. (2024). Educational technology integration as a driver of sustainable development competencies among secondary school students. *Journal of Education and Learning Research, 5*(2), 45–59.

Okon, E. J. (2025). Barriers to effective integration of ICT and 21st century skills in Nigerian secondary schools. *International Journal of Innovation in Education, 18*(6), 115–129.

Okonkwo, B. U., & Uche, I. K. (2025). Exam-driven culture and the neglect of 21st century skills in Nigeria: Implications for educational sustainability. *Nigerian Journal of Pedagogy, 14*(1), 73–88.

Okonkwo, E. A., & Ezeonwuka, C. I. (2023). Enhancing sustainable education through digital pedagogy in Anambra State public schools: Challenges and policy directions. *African Journal of Educational Research and Development, 17*(2), 67–79.

Piaget, J. (1972). *The psychology of the child*. Basic Books.

Tabachnick, B. G., & Fidell, L. S. (2023). *Using multivariate statistics* (8th ed.). Pearson.

Umar, M. A., & Bello, H. T. (2025). Impact of 21st century skills acquisition on sustainable development competencies of secondary school students in Nigeria. *Contemporary Educational Research Journal, 9*(6), 72–88.

UNESCO. (2023). *Reimagining our futures together: A new social contract for education*. United Nations Educational, Scientific and Cultural Organization. https://unesdoc.unesco.org

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Wiek, A., Withycombe, L., & Redman, C. L. (2025). Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science, 14*(5), 61–76.