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Assessing the Relationship Between ICT Infrastructure and Educational Communication for Sustainable Urban Development in Ekiti State, Nigeria

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Abstract: Information and Communication Technology (ICT) Infrastructure is an important tool that is essential in promoting educational communication (EC) and sustainable urban development (SUD). In this paper, the aim was to evaluate the relationship between ICT Infrastructure (ICTI) and EC in the context of SUD in Ekiti State, Nigeria. The research design employed was the descriptive cross-sectional survey design where some educational institutions in Ado-Ekiti, Oye-Ekiti, Ikere-Ekiti, Ikole-Ekiti, and Ijero-Ekiti, including Ekiti State University (EKSU), Federal University Oye-Ekiti (FUOYE), Federal Polytechnic and secondary schools were chosen. Determination of sample size was done where the sample size determined was 427, while 420 responses were found to be valid. The respondents were students, lecturers, teachers, and ICT personnel. In the process of data collection, the use of structured questionnaire was done where the questionnaire was developed in the context of ICTI, ICT accessibility (ICTA), ICT utilization (ICTU), EC, and SUD. Cronbach's alpha for the test of internal consistency of the instrument was found to be 0.91. Regression analysis showed that there was a high degree of positive relationship between ICT and EC (R = 0.846, R^2 = 0.716, β = 0.846, F = 1053.83). Hence, it can be stated that ICTI is significantly associated with EC in the chosen educational institutions. It is recommended by the study that ICTI is a means through which better EC and sustainable development can be achieved.

Keywords: ICT infrastructure, educational communication, sustainable urban development, educational institutions, Ekiti State

1. Introduction

1.1. Background

Information and Communication Technology (ICT) has been recognized as a component of educational communication (EC) by providing means of information exchange, digital learning, research collaboration, and access to educational materials. The use of ICT in education is dependent on the presence of technology infrastructure, access to technology, effectiveness of such infrastructure, and how it is used. ICT use in Nigeria offers an opportunity for improving EC, although the differences in infrastructure presence and accessibility can play a role in making the advantages of using ICT felt. Fakunle and Ajani [1] focused on peculiarities of ICT use in Nigeria, offering the contextual background of ICT integration. Likewise, Okundaye et al. [2] enriched the existing discussion of ICT-related educational issues, emphasizing the need to analyze technology in terms of its functioning context.

The ICTI includes internet connection, computers, mobile phones, communication networks, digital media, and related technical facilities. The ICTI enables communication among teachers, students, researchers, administrators, and institutions of education. Nevertheless, ICTI does not automatically provide good EC. Its effectiveness depends on its cost, proficiency in using ICTs, accessibility, and relevance of available services. The

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contribution by Kaur [3] can be used as a background for ICTA and use in more general discussions on technologies and education. Adebanjo et al. [4] and Ajibade and Zaidi [5] make additional contributions to the discussion on ICT adoption and technology-mediated activities.

The relation between the ICTI and EC needs to be studied in order to understand how technological infrastructure correlates with information exchange and EC processes. Different ICTI (connectivity, hardware, and resources available in institutions) may correspond to different ways of accessing learning resources, communicating about academic information, and carrying out educational activities in digital environment. Such a study may be relevant for sustainable urban development (SUD) because communication, information access, and human capacity building are significant aspects of such development.

SUD entails enhancing the social, economic, and institutional aspects that facilitate sustainable community welfare. ICT can make its own contribution to the above objectives through the dissemination of knowledge, education, and information access. However, the degree of contribution of ICT to SUD depends on local circumstances and how technological capabilities are employed. The present research is entitled Assessing the Relationship Between ICT infrastructure and EC for SUD in Ekiti State, Nigeria, and evaluates the relationship between ICTI and EC without making any assumption of causality or taking SUD as an observable variable.

Apart from facilitating academic activities, EC facilitated by ICTI contributes toward the accomplishment of social and economic development goals. The development of EC leads to knowledge sharing and digital literacy, which further help in the development of sustainable cities via human capital development, efficiency of institutions, digital inclusion, and education. According to Adebanjo et al. [4], the effective use of ICT contributes toward the exchange of information between the university students. Besides this, the importance of technology acceptance and utilization in improving e-learning communication in higher educational institutions has been identified by Ajibade and Zaidi [5]. Increased access to ICT resources and information exchange platforms would help the educational institutions and their members to develop their technological skills, exchange information, and engage in the knowledge-based society.

Therefore, ICT-based educational systems could have an enabling effect on the achievement of SDGs 4 and 11 through quality education, lifelong learning, digital inclusion, and resilient societies. In this respect, ICTI could be considered as a facilitator of human capital development, institutional efficiency, and education.

Nowadays, the development of sustainability in urban settings relies increasingly on communication infrastructure that would facilitate the conduct of education, innovations, institutional efficiency, and inclusiveness. The educational institutions operating in the urban and semi-urban environments require the use of the ICTI to facilitate the process of e-learning, collaboration, information, and communication between all participants of the educational process. Osiesi et al. [2] argued that the presence and accessibility of ICT were crucial factors affecting the efficiency of EC, while Olowo et al. [6] found that ICT-enabled communication could facilitate information exchange and communication in the educational environment.

Although ICT has been incorporated into educational systems, there are various limitations including insufficient infrastructure, problems with accessibility, digital divide, and ineffectiveness of ICT system usage in the process of education. As stated by Fakunle and Ajani [1], there are some barriers in the implementation of ICT in Nigeria, and according to Kaur [3], there are some technical and pedagogical barriers that prevent the efficient use of ICT in the education system. Such barriers may prevent educational institutions from using ICT technology to deliver knowledge and run sustainable development programs. Thus, it is important to conduct empirical research in order to examine the relationship between ICTI, EC efficiency, and SUD, particularly, in Ekiti State of Nigeria.

1.2. Review of related work

1.2.1. ICT infrastructure, adoption, and accessibility

Studies on ICT adoption highlight the need for a thorough understanding of the situation in which individuals and institutions have access and make use of ICTs. Background material on the use of technology in educational and institutional settings is provided by the works of Olowo et al. [6]. Another contribution to the subject of ICT adoption and ICT adoption determinants comes from the work of Okundaye et al. [7]. These contributions provide good reason for studying ICT as a technology tool and activity affected by its users' situations.

Availability of infrastructure is one aspect that must be taken into consideration in the evaluation of EC since it involves using technology, which in turn involves access to the necessary devices and facilities. Nevertheless, the availability of the mentioned resources does not mean that users are able to access them or use them in an effective manner. Contributions to the topic of access to information through technology and communication are provided by Hafa and Moubtassime [8] and Hailegebreal et al. [9].

ICTI may provide facilities for electronic communication, availability of digital learning resources, and the exchange of academic information within the context of education. In circumstances where connectivity is not stable and there are no devices, these processes can be limited. On the other hand, where there is access to stable ICTI, interactions become easier. This needs to be empirically verified.

1.2.2. ICT utilization and educational communication

Communication in education is the sharing of information between students, lecturers, researchers, managers, and other people involved in the educational process. It encompasses classroom communication, announcements, scholarly communication, collaboration, feedback, and distribution of study materials. Information and communications technology offers means by which these processes may be carried out beyond the traditional limits of face-to-face communication.

Olajide and Adedokun [10] offer a pertinent insight into the role of ICT in the context of education, whereas the work of Olagbaju and Popoola [11] offers further insight on this issue. This literature aids in highlighting the significance of studying how ICTs are used in educational activities. However, having communication platforms is different from using them.

1.2.3. ICT-supported learning and electronic information access

Another important element of technology-assisted learning is the availability of educational information. ICT allows the user to access various electronic sources, communicate with the tutor, engage in online discussions, and receive educational content. All these actions can be used to enhance the traditional

way of learning especially where the learner needs flexible access to information (Eiriemiokhale & Sulaiman [12]; Kaur [13]). The ICT framework can help in EC by using internet-enabled gadgets, networked facilities in institutions, e-mail service, learning management systems, and online information services. Such facilities can help in fast dissemination of educational content, geographical communication, and more chances for collaboration (Eiriemiokhale & Sulaiman [12]; Kaur [13]; Ruth et al. [14]).

Other studies conducted by Eze et al. [15] and Olojo et al. [16] shed light on technology adoption and education outcomes in Nigeria. Despite the fact that these studies examine various issues related to technology usage and education performance, they can be used as a background for analyzing the relevance of ICT-based activities for education. Digital information availability is just one of the aspects of the connection between technological facilities and EC. The value of these activities depends on users' accessibility conditions, technology adoption, and implementation of ICT resources in education (Eiriemiokhale & Sulaiman [12]; Ruth et al. [14]). In addition to this, users' ability to adopt and utilize these technologies will determine how much these facilities will facilitate communication and information sharing (Ruth et al. [14]; Eze et al. [15]). Nevertheless, the effectiveness of these communication tools needs to be evaluated systematically through the use of certain measures of ICTA, ICT usage, education communication, and learning assistance (Eze et al. [15]; Olojo et al. [16]).

1.2.4. Institutional and contextual considerations

ICTI and EC may have varying relationships owing to various institutional and contextual variations. Availability of resources, technical assistance, competence of users, among others may influence how ICT facilities are utilized. Therefore, conclusions drawn in one instance cannot justifiably be applied to another.

Contextual literature provided by Isinkaye et al. [17] is helpful for informing technological and institutional considerations of the present study. Babalola and Hulla [18] as well as Christopher [19] provide further literature for informing contextual considerations of development-oriented activities. Although these references are useful for placing the present research within the context of existing literature, they cannot be considered as direct evidence for any relationship between ICTI and EC, unless the findings specifically prove the link.

Ejiko et al. [20] and Nwoke et al. [21] add more references for the contextual literature pertaining to the setting of the research and its development concerns. These references will help in understanding better the context of the environment within which EC takes place. Nonetheless, the core question of this research is the existence of any difference in the ICTI in relation to EC among the population studied in Ekiti State.

1.2.5. ICT and sustainable urban development

Adequate provision for information access, education, institutional capability, and the conditions necessary for community participation are required for SUD. ICTI may assist in this respect through providing means of communication and knowledge access. It can be thus argued that EC can be regarded as a possible avenue by which ICTI could help sustainable development objectives.

Virginia [22] provides contextual literature for the general development discussion. Nevertheless, the link between ICTI and SUD should be understood in this context carefully. Access improvements do not automatically lead to sustainable development outcomes, and the current study will not assume such an impact of infrastructure on educational and urban development performance.

The present study, therefore, explores the relationship between ICTI and EC in Ekiti State. SUD forms a broad policy context for such exploration. It helps to explore a particular link while being aware that other factors can also influence development outcomes.

1.3. Synthesis of literature

The reviewed literature emphasizes the significance of ICTI in facilitating EC, digital learning, information access, and institutional interaction. Prior research works have covered ICT adoption, technological access, educational technology use, and developmental concerns [1–22]. Altogether, the above discussions suggest that the provision of internet connectivity, technological devices, communications, and online technologies enables the exchange of educational information. However, efficient EC might also depend on issues such as cost, network reliability, digital competence, technological assistance, and institutional practices.

Moreover, the reviewed literature underscores the significance of differentiating ICTI availability from its actual contribution to EC. Availability of technological facilities does not imply their actual use or accessibility by educational participants. Also, while ICT can facilitate the process of knowledge transfer and educational participation, its contribution to SUD needs to be examined in broader social, economic, and institutional contexts.

However, there is a need for context-specific evaluation of the association between ICTI and education communication in Ekiti State. This research will fill this vacuum through investigation of the infrastructure and communication elements related to the chosen research sample population. Methodological aspects of this study will be followed to measure and evaluate the association [23, 24]. The results are expected to provide empirical support to assist in education ICT planning and infrastructure development in Ekiti State, Nigeria.

1.4. Research gap

While existing research has looked at ICT adoption, digital accessibility, technology-enabled learning, and information sharing [1–22], little context-specific evidence has been generated regarding the link between ICTI and EC in Ekiti State, Nigeria. There is extensive literature on how ICTs are used and the possible benefits from education. However, the presence of technological tools does not mean they can be easily accessed, reliable, and effective in facilitating EC.

Moreover, while ICTI and EC are regarded as related elements of digital development, there is a need for empirical evaluation of the connection between these two elements in specific geographical and institutional settings. Internet connections, access to digital gadgets, network dependability, and technological abilities of users might vary in correspondence with educational information exchange and communication. Thus, the link between these elements needs further examination in Ekiti State.

A related gap is that of the relationship between EC and SUD as a larger goal. While ICT can assist with knowledge sharing, education, and institutional capacity building, the contribution that can be made by ICT within such a context needs to be explored.

In order to bridge these gaps, the research will endeavor to examine the relationship between ICTI and EC in Ekiti State, Nigeria. Through a study of the infrastructure and communication-related variables in the area, there will be generation of context-based information, which can be useful for ICT planning, EC, and sustainable development.

1.5. Aim and objectives of the study

This research seeks to assess the relationship between ICTI and EC for SUD in Ekiti State, Nigeria.

To be able to achieve this goal, the research will:

1) Assess the availability of ICTI in educational institutions in Ekiti State.
2) Assess the level of use of ICT in EC.
3) Assess the link between ICTI and EC effectiveness.
4) Assess the contribution made by ICT-based EC toward SUD in Ekiti State.
5) Assess the factors that affect ICTI in educational institutions.

2. Materials and Methods

The current study adopted a systematic approach, which was designed to establish the link between ICTI on education and SUD in Ekiti State, Nigeria. This methodology outlines the research design, study area, sample selection, data collection methods, reliability of measuring instruments, and methods of data analysis among other important factors.

2.1. Research design

In conducting the evaluation on the influence of ICTI on EC for SUD in Ekiti State, Nigeria, descriptive survey research design was employed. This is because through the design, the researcher had a chance to collect both quantitative and qualitative data from the respondents without manipulating the variables. The design was appropriate for studying the relationships between the existence, availability, accessibility, and effectiveness of ICTI in terms of EC. The functional relationship was stated as

$$SUD_i = f(ICTI_i, EC_i, \mathbf{Z}_i) + \varepsilon_i, \quad (1)$$

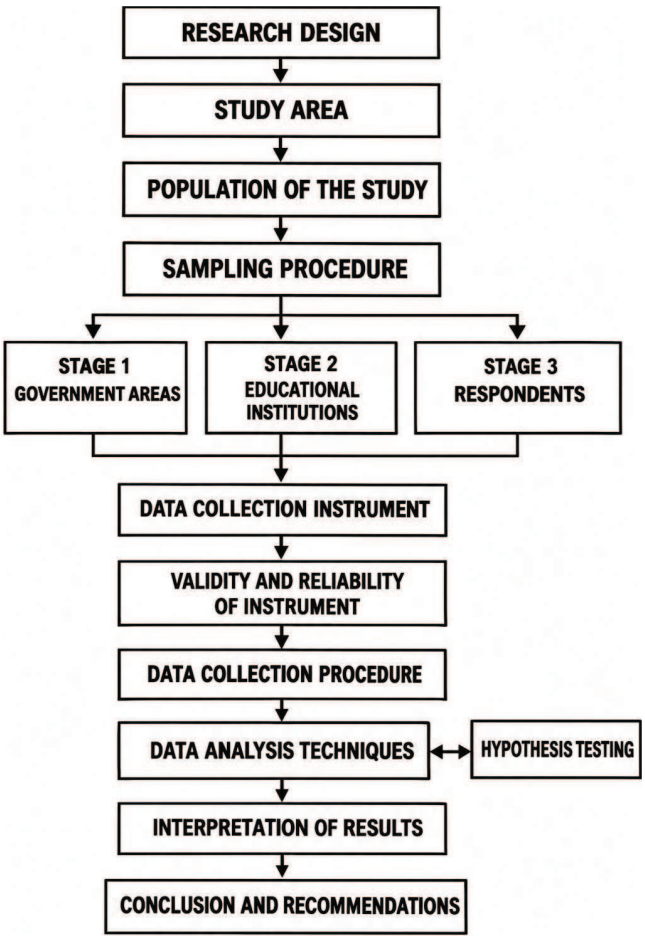
where SUD_i represented the SUD score for respondent i, $ICTI_i$ represented the ICTI score, ECi represented the EC score, Z_i represented other observed respondent or institutional characteristics where applicable, and ε_i represented the unexplained component of the model. Equation (1) provided the mathematical representation of the empirical framework without implying causal direction.

Systematic and sequential research methodology was used in order to ensure scientific research procedure in terms of its reliability and validity in all steps of the research process. The research methodology includes such components as research design, research area, population, sampling, data collection, validation of research tools, data analysis, and hypothesis testing. The whole methodological process is demonstrated in Figure 1.

2.2. Study area

This study was conducted in Ekiti State of Nigeria. The five major education zones in this study include Ado-Ekiti, Oye-Ekiti, Ikere-Ekiti, Ikole-Ekiti, and Ijero-Ekiti. The abovementioned five zones had various institutions such as universities, polytechnics, colleges of education, and secondary schools that facilitated ICT-enabled teaching, information exchange, and communication.

Figure 1
Methodological flowchart of the study design and procedures



Inclusion of the abovementioned zones for the purpose of this study ensured geographical and institutional diversity to assess ICTI, ICT access, ICT use, EC, and SUD perception.

2.3. Study population

The accessible population included lecturers, teachers, ICT personnel, administrators, and undergraduate students of selected educational institutions within the five study zones. The accessible population included

$$N = \sum_{h=1}^{H} N_h = 12,480, \quad (2)$$

where N represented the total accessible population, N_h represented the population in stratum h, and H represented the total number of institutional strata.

The population composition was represented generally as

$$N = N_L + N_T + N_I + N_A + N_S, \quad (3)$$

where N_L, N_T, N_I, N_A, and N_S represented lecturers, teachers, ICT staff, administrators, and undergraduate students,

respectively. This formulation represented the aggregation of the identified stakeholder categories into the accessible study population.

2.3.1. Sample size determination

The minimum sample size was determined using Yamane's finite-population formula:

$$n_0 = \frac{N}{1 + Ne^2}, \tag{4}$$

where n_0 represented the initial sample size, N represented the accessible population, and e represented the specified margin of sampling error.

With N = 12,480 and e = 0.05, the required initial sample was calculated as

$$n_0 = \frac{12{,}480}{1 + 12{,}480\,(0.05)^2}.$$

Thus,

$$n_0 = \frac{12{,}480}{1+31.2} = \frac{12{,}480}{32.2} \approx 387.58.$$

The minimum sample size was consequently rounded upward to

$$n = 388.$$

To compensate for possible non-response and incomplete questionnaires, a 10% adjustment was applied. The adjusted sample size was determined as

$$n_a = \frac{n}{1-r}, \tag{5}$$

where na represented the adjusted sample size and r = 0.10 represented the anticipated non-response proportion.

Hence,

$$n_a = \frac{388}{1-0.10} = \frac{388}{0.90} \approx 431.11.$$

On the other hand, the target for field administration was 427 questionnaires, which constituted the sample size for questionnaire administration. Thus, 427 questionnaires were administered while 420 were analyzed in the final analysis.

2.4. Sampling procedure

The multistage sampling technique was employed. The first stage was that of purposive sampling of the five locations where the research was conducted. The second stage was stratifying the sample according to institutions, that is, universities, polytechnics, colleges of education, and secondary schools. The third stage was employing simple random sampling of the respondents in the defined strata.

This was done through proportionate allocation of the sample to the strata. The number of respondents to be allocated to stratum h was determined through

$$n_h = n\frac{N_h}{N}, \tag{6}$$

where n_h represented the number of respondents allocated to stratum h, n represented the total planned sample, N_h represented the population of stratum h, and N represented the total accessible population.

For example, for the Federal University Oye-Ekiti stratum, with N_h = 3,200, N = 12,480, and n = 427,

$$n_h = 427\left(\frac{3{,}200}{12{,}480}\right).$$

Therefore,

$$n_h \approx 109.54 \approx 110.$$

Thus, 110 respondents were allocated to the FUOYE stratum. The same proportionate allocation principle was applied to the other institutional strata.

The final valid respondents were distributed across the study locations as follows: 110 respondents from Ado-Ekiti, 92 from Oye-Ekiti, 80 from Ikere-Ekiti, 70 from Ikole-Ekiti, and 68 from Ijero-Ekiti, giving

$$n_f = 110 + 92 + 80 + 70 + 68 = 420.$$

The corresponding percentage representation of each location was calculated using

$$P_h = \frac{n_h}{n_f} \times 100, \tag{7}$$

where P_h represented the percentage contribution of location h to the final analytical sample.

2.4.1. Respondents distribution and handling of respondents

The respondents' distribution among the five locations that were selected for this research work is shown in Table 1. The respondents' distribution was such that there would be geographical and institutional representation within the research area.

Distribution indicates that the number of the sample size used was 420 individuals in total, taking into account the five institutions used in this study. The largest number of participants were found in Ado-Ekiti (26.2%); followed by Oye-Ekiti (21.9%), Ikere-Ekiti (19.0%), Ikole-Ekiti (16.7%), and finally Ijero-Ekiti (16.2%). Nonetheless, variation existed in the results of description in relation to ICTI and EC within the selected areas for this research. Nonetheless, it is worth noting that this variation is not statistically significant because there is no hypothesis testing carried out among the locations.

Combining different groups of people such as students, lecturers, teachers, and ICT professionals into one sample of respondents may pose difficulties because of respondent heterogeneity as the various stakeholder categories have different level of exposure to ICT infrastructure and EC. However, combining of respondents was right since the research was carried out at an institutional level, and its aim was to find out the relationship between ICT infrastructure, EC, and SUD without focusing on occupational findings.

2.5. Research instrument and data collection

The main instrument for data collection was the structured questionnaire. The questionnaire consisted of six sections, namely demographics, ICTI, ICT access, ICT use, education communication, and SUD.

The final questionnaire had 48 measures arranged into five constructs:

$$J = \sum_{c=1}^{5} J_c = 12 + 8 + 8 + 10 + 10 = 48,$$

Table 1
Distribution of respondents across study locations and institution types

Town	Institution	Institution Type	Valid Respondents	Percentage (%)
Ado-Ekiti	EKSU/Selected Schools	University/Secondary	110	26.2
Oye-Ekiti	FUOYE	University	92	21.9
Ikere-Ekiti	Bamidele Olumilua University of Science and Technology	University	80	19.0
Ikole-Ekiti	FUOYE-Ikole Campus	University	70	16.7
Ijero-Ekiti	Ekiti State College of Health Science and Technology	Polytechnic	68	16.2
Total			420	100.0

where J represented the total number of substantive measurement items and Jc represented the number of items assigned to construct c.

The constructs were defined as follows:

1) ICT infrastructure (ICTI): 12 items;
2) ICT Accessibility (ICTA): 8 items;
3) ICT Utilization (ICTU): 8 items;
4) Educational Communication (EC): 10 items;
5) Sustainable Urban Development (SUD): 10 items.

All substantive items were measured using a five-point Likert scale:

$$x_{ij} \in \{1, 2, 3, 4, 5\}, \tag{8}$$

where 1 represented strongly disagree, 2 represented disagree, 3 represented neutral, 4 represented agree, and 5 represented strongly agree.

2.5.1. Questionnaire development and construct scoring

The structured questionnaire instrument was constructed for the purpose of gathering quantitative data on ICTI, ICTA, ICTU, EC, and SUD within selected educational institutions in Ekiti State. The construction of the questionnaire was guided by the research objectives, conceptual framework, operationalization of study variables and empirical findings in the extant ICT adoption and utilization literature, and EC and sustainable development literature. The initial set of questionnaire items was derived from the empirical literature and tailored to suit the technological context in Ekiti State.

At first, 60 questionnaire items were constructed based on the research objectives and the conceptual framework and guided by the empirical literature. These items underwent expert judgment in order to determine their relevancy, appropriateness, clarity, representativeness, and consistency with the constructs under study. Altogether, three experts familiar with Educational Technology, ICT, and Communication Engineering, respectively, independently evaluated the initial questionnaire items.

Out of the 60 items that were reviewed by the experts, only 58 were considered relevant and appropriate for the measurement of the study variables and consequently resulted in a content validity index (CVI) of 0.967. Items that were redundant, ambiguous, and inconsistent with the operational definition of the study variables were removed or reformulated. This process led to the development of a final questionnaire that had 48 items arranged according to five different constructs; Information and Communications Technology Infrastructure (12 items), ICTA (8 items), ICTU (8 items), Education Communication (10 items), and SUD (10 items).

All the constructs stated above were measured using a five-point likert scale where one means strongly disagree and five strongly agree. ICTI included internet connectivity, computer laboratory, digital learning infrastructure, network infrastructure, and power supply. ICTA included availability of ICT facilities, availability of digital resources, accessibility, and availability of ICT services. ICTU included frequency of ICT usage, ICT use, online learning platforms, and ICT-aided educational activities. Educational communication included lecturer–student communication, educational information exchange, collaboration, digital learning, and knowledge exchange. SUD included educational quality, human capital development, institutional efficiency, digital inclusion, knowledge exchange and sustainable education, and smart governance.

A 48 items questionnaire was then pretested among 40 people whose demographics were similar to that of the target population but were not part of the sample in the study. The aim of carrying out this pilot test was to test the clarity and consistency of the questionnaire before data collection process begins. Analysis of data was done using IBM SPSS Statistics version 29 and Cronbach's alpha coefficients were calculated for the different constructs. The Cronbach's alpha coefficient values of all constructs varied from 0.89 to 0.94 with an overall value of 0.91.

For respondent i, the raw score for construct c was represented as

$$X_{ic} = \sum_{j=1}^{m_c} x_{icj}, \tag{9}$$

where X_{ic} represented the raw score of respondent i on construct c, m_c represented the number of items measuring construct c, and x_{icj} represented the Likert response to item j.

Because the constructs contained different numbers of items, the mean construct score was calculated as

$$\overline{X}_{ic} = \frac{1}{m_c} \sum_{j=1}^{m_c} x_{icj}. \tag{10}$$

Equation (9) transformed each construct into a common 1–5 metric and therefore permitted direct comparison among ICTI, ICTA, ICTU, EC, and SUD despite differences in the number of questionnaire items.

Where standardized construct scores were required, they were calculated as

$$Z_{ic} = \frac{\bar{X}_{ic} - \mu_c}{\sigma_c}, \quad (11)$$

where μ_c and σ_c represented the sample mean and standard deviation of construct c.

2.5.2. *Descriptive measurement criterion*

The theoretical mean of the five-point response scale was calculated as

$$\mu_L = \frac{\sum_{k=1}^{5} k}{5} = \frac{1+2+3+4+5}{5} = 3.00.$$

For a construct containing m items and n_f respondents, the overall construct mean was calculated as

$$\bar{X} = \frac{1}{n_f m} \sum_{i=1}^{n_f} \sum_{j=1}^{m} x_{ij}. \quad (12)$$

A mean score of $\bar{X} \geq 3.00$ was interpreted as agreement or a relatively positive perception, whereas $\bar{X} < 3.00$ was interpreted as disagreement or a relatively negative perception.
The standard deviation was calculated as

$$s = \sqrt{\frac{\sum_{i=1}^{n_f} (x_i - \bar{x})^2}{n_f - 1}}. \quad (13)$$

The equation quantified the dispersion of responses around the sample mean.

The questionnaire items have been modified to fit the needs of the current study carried out in Ekiti State, Nigeria. As shown in Table 2 presented below, the instrument included a total of forty-eight (48) items categorized into five main constructs, which are ICTI, ICTA, ICTU, EC, and SUD.

Table 2
Distribution of questionnaire items across study variables

Variable	Number of Items
ICT Infrastructure	12
ICT Accessibility	8
ICT Utilization	8
Educational Communication	10
Sustainable Urban Development	10
Total	48

The variables that were considered for the infrastructure variable were internet connectivity, computer labs, digital learning infrastructure, networking, and electricity stability. For the accessibility and utilization of ICT and EC, the focus was on the respondents availability to ICT and their use and interactions between the lecturer and students, respectively, and finally digital learning. Some other variables, including quality of education, human capital development, digital inclusion, institutional effectiveness and sustainability of education, and urban development were captured under SUD variable.

A five-point Likert scale was used in the questionnaire to gauge the level of agreement of the respondents to the statements. The options and their respective weights are provided in the Table 3.

Table 3
Five-point likert response scale and weighting

Response	Weight
Strongly Agree (SA)	5
Agree (A)	4
Neutral (N)	3
Disagree (D)	2
Strongly Disagree (SD)	1

Five-point Likert scale is used due to its simplicity, reliability, and relevance for measuring people's attitudes, perceptions, and views using surveys. In turn, each person had to express his/her level of agreement regarding a specific statement on the basis of the given options. It has allowed quantifying ICTI, accessibility and utilization, EC, and SUD in chosen educational organizations.

The mean decision criterion was calculated using the following formula:

$$\dot{x} = \frac{5+4+3+2+1}{5} = 3.00$$

An average value of 3.00 or higher indicated an agreement with or a favorable view of the variable being measured, whereas an average value of less than 3.00 indicated a disagreement with or an unfavorable view of the variable. The application of the aforementioned rule provided a systematic method of interpreting the descriptive statistics of the survey data.

2.6. Operationalization and measurement of variables

ICT resources' availability, accessibility, reliability, and adequacy were some of the factors that were considered during the measurement of the level of ICTI. Education communication was operationalized by taking into account the indicators related to information sharing, provision of digital learning assistance, effectiveness of communication, and knowledge dissemination. The construct of SUD was measured by taking into account the perceived indicators of education quality, human capital development, effectiveness of institutions, digital inclusion, knowledge sharing, and smart governance. In measuring the response for each indicator, five-point Likert Scale was used which had 1 for "strongly disagree" and 5 for "strongly agree".

The operationalization and measurement of study variables took place with the help of formulation and adaptation of constructs based on research objectives from the past studies about ICT adoption, ICT usage, EC, and sustainable development in educational contexts [1, 4, 7, 8, 23]. The five main dimensions in which the constructs were measured include ICTI, ICTA, ICTU, EC, and SUD. This was done with the help of indicators measuring availability, accessibility, usage, and effect of ICT-based EC.

The measurement structure was represented generally by

$$x_{ic} = \lambda_c \eta_{ic} + \delta_{ic}, \quad (14)$$

where x_{ic} represented the observed questionnaire indicators for construct c, λ_c represented the vector of indicator loadings,

Table 4
Operationalization and measurement of study variables

Construct	Indicators/Measurement Dimensions	Number of Items	Measurement Scale
ICT infrastructure	Internet connectivity, computer laboratories, digital learning infrastructure, networking facilities, and electrical stability	12	Five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree)
ICT Accessibility	Access to ICT facilities, availability of digital resources, ease of access, and affordability of ICT services	8	Five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree)
ICT Utilization	Frequency of ICT usage, application of digital tools, use of online learning platforms, and ICT-supported academic activities	8	Five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree)
Educational Communication	Lecturer–student interaction, communication of educational information, collaborative learning, digital learning support, and knowledge dissemination	10	Five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree)
Sustainable Urban Development	Educational quality, human capital development, institutional efficiency, digital inclusion, knowledge sharing, and support for sustainable education and smart governance	10	Five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree)

η_{ic} represented the underlying construct score, and δ_{ic} represented measurement error.

The detailed description of the constructs, measurement indicators, questionnaire items, and scaling is presented in Table 4.

2.7. Validity of the research instrument

Content validity was assessed by three experts in Educational Technology, ICT, and Communication Engineering. The content validity index (CVI) was calculated as

$$\mathrm{CVI} = \frac{N_r}{N_t}, \tag{15}$$

where N_r represented the number of items judged relevant by the experts and N_t represented the total number of items submitted for review.

For the 60 preliminary items, 58 were considered relevant. Therefore,

$$\mathrm{CVI} = \frac{58}{60} = 0.9667 \approx 0.967.$$

The CVI therefore represented the proportion of preliminary questionnaire items judged relevant during the expert-review process.

Where item-level agreement was considered, the item-level content validity index was represented as

$$\mathrm{I-CVI_j} = \frac{n_{rj}}{N_E}, \tag{16}$$

where n_{rj} represented the number of experts rating item j as relevant and N_E represented the total number of experts.

2.7.1. Reliability assessment using Cronbach's alpha

A pilot survey involving 40 respondents with characteristics similar to the target population was conducted before the main survey. Cronbach's alpha was used to assess the internal consistency of the questionnaire.

For a construct containing k items, Cronbach's alpha was calculated as

$$\alpha = \frac{k}{k-1}\left[1 - \frac{\sum_{j=1}^{k}\sigma_j^2}{\sigma_T^2}\right], \tag{17}$$

where α represented Cronbach's alpha, k represented the number of questionnaire items, σ_j^2 represented the variance of item j, and σ_T^2 represented the variance of the total construct score.

The total-score variance was represented as

$$\sigma_T^2 = Var\left(\sum_{j=1}^{k} X_j\right). \tag{18}$$

Equation (17) described the consistency within the scale by measuring the total variance of all items against the variance of the composite score of the construct.

The reliability coefficients of the constructs measured were ICTI (0.91), ICTA (0.89), ICTU (0.92), EC (0.94), and SUD (0.90). The general reliability coefficient was 0.91.

A pilot study was done on 40 participants who shared the same characteristics with the population under study but were not part of the actual sampling process. The objective of this pilot study was to evaluate the internal consistency, understandability, and reliability of the questionnaire before the data collection process. This was done with the aid of IBM SPSS Statistics Version 29 software, and Cronbach's alpha values were obtained for each construct.

The results of the reliability calculation are provided in Table 5. The calculated values of Cronbach's alpha ranged

Table 5
Reliability assessment of the research instrument using Cronbach's alpha

Construct	Number of Items	Cronbach's Alpha (α)
ICT infrastructure	12	0.91
ICT Accessibility	8	0.89
ICT Utilization	8	0.92
Educational Communication	10	0.94
Sustainable Urban Development	10	0.90
Overall Reliability	48	0.91

between 0.89 and 0.94, which gives the general value of reliability coefficient of 0.91. All these values were higher than the minimum value of reliability, which was considered acceptable and equal to 0.70 [20, 23]. Therefore, one can assume that the internal consistency and reliability of the research instrument in terms of measuring ICTI, ICTA, ICT use, EC, and SUD is quite high.

The overall reliability coefficient was calculated as:

$$\alpha = 0.91$$

It means that the instrument has good internal consistency reliability and is suitable for the evaluation of the study variables.

The reliability of the questionnaire was determined by using Cronbach's alpha, with an alpha value of 0.91 being attained, which surpasses the required level of 0.70 and therefore represents excellent internal consistency.

2.8. Data collection and response rate

A total of 427 questionnaires were distributed to respondents in the selected educational institutions. After screening, 420 questionnaires were retained as valid responses.

The valid response rate was calculated as

$$\mathrm{RR} = \frac{\mathrm{n_v}}{\mathrm{n_d}} \times 100,$$

where RR represented the valid response rate, $\mathrm{n_v}$ represented the number of valid questionnaires, and $\mathrm{n_d}$ represented the number of questionnaires distributed.

Thus,

$$\mathrm{RR} = \frac{420}{427} \times 100 = 98.36\%$$

The 420 valid observations constituted the final analytical dataset.

2.9. Conceptual framework and system model

The conceptual framework represented ICTI as the explanatory construct, EC as an intermediate construct, and SUD as the outcome construct.

ICTI was represented as

$$\mathrm{ICTI_i} = f(\mathrm{I_i}, \mathrm{A_i}, \mathrm{U_i}), \tag{19}$$

where $\mathrm{I_i}$ represented ICTI availability and adequacy, $\mathrm{A_i}$ represented accessibility, and $\mathrm{U_i}$ represented utilization.

A composite representation was expressed as

$$\mathrm{ICTI_i} = \mathrm{w_1 I_i} + \mathrm{w_2 A_i} + \mathrm{w_3 U_i}, \sum_{r=1}^{3} \mathrm{w_r} = 1, \tag{20}$$

where $\mathrm{w_r}$ represented the weighting assigned to each component.

When equal weighting was adopted,

$$\mathrm{w_1} = \mathrm{w_2} = \mathrm{w_3} = \frac{1}{3}. \tag{21}$$

EC was represented as a function of ICT-related dimensions:

$$\mathrm{EC_i} = f(\mathrm{ICTI_i}, \mathrm{ICTA_i}, \mathrm{ICTU_i}) + \varepsilon_{1i}. \tag{22}$$

The corresponding linear model was expressed as

$$\mathrm{EC_i} = \beta_0 + \beta_1 \mathrm{ICTI_i} + \varepsilon_{1i}. \tag{23}$$

Equation (22) modeled the statistical association between ICTI and EC.

SUD was represented as

$$\mathrm{SUD_i} = f(\mathrm{ICTI_i}, \mathrm{EC_i}) + \varepsilon_{2i}. \tag{24}$$

The empirical multiple regression model was specified as

$$\mathrm{SUD_i} = \beta_0 + \beta_1 \mathrm{ICTI_i} + \beta_2 \mathrm{EC_i} + \varepsilon_{2i}. \tag{25}$$

Equation (24) modeled the joint statistical association of ICTI and EC with SUD.

The complete two-equation system was represented as

$$\begin{cases} \mathrm{EC_i} = \beta_{01} + \beta_{11} \mathrm{ICTI_i} + \varepsilon_{1i}, \\ \mathrm{SUD_i} = \beta_{02} + \beta_{12} \mathrm{ICTI_i} + \beta_{22} \mathrm{EC_i} + \varepsilon_{2i}. \end{cases} \tag{26}$$

The first equation represented the ICTI–EC relationship, whereas the second represented the joint association of ICTI and EC with SUD.

2.10. Ordinary least-squares estimation

The regression equations were estimated using ordinary least squares (OLS). The general linear model was expressed as

$$y = X\beta + \varepsilon, \tag{27}$$

where y represented the dependent-variable vector, X represented the matrix, β represented the vector of regression coefficients, and ε represented the error vector.

The OLS estimator was calculated as

$$\hat{\beta} = \left(\mathrm{X^T X}\right)^{-1} \mathrm{X^T y}. \tag{28}$$

For the simple regression model, the slope coefficient was estimated as

$$\hat{\beta}_1 = \frac{\sum_{i=1}^{n_f}(x_i-\bar{x})(y_i-\bar{y})}{\sum_{i=1}^{n_f}(x_i-\bar{x})^2}. \quad (29)$$

The intercept was calculated as

$$\hat{\beta}_0 = \bar{y} - \hat{\beta}_1\bar{x}. \quad (30)$$

These equations defined the fitted regression relationship using the observed construct scores.

2.10.1. Correlation analysis

The Pearson correlation coefficient was calculated using

$$R = \frac{\sum_{i=1}^{n_f}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n_f}(x_i-\bar{x})^2\sum_{i=1}^{n_f}(y_i-\bar{y})^2}}. \quad (31)$$

The coefficient quantified the direction and strength of the linear association between two continuous composite scores.

2.10.2. Coefficient of determination

The coefficient of determination was calculated as

$$R^2 = 1 - \frac{SSE}{SST}, \quad (32)$$

where SSE represented the residual sum of squares and SST represented the total sum of squares.

The residual sum of squares was calculated as

$$SSE = \sum_{i=1}^{n_f}(y_i\text{-}\hat{y}_i)^2, \quad (33)$$

while the total sum of squares was calculated as

$$SST = \sum_{i=1}^{n_f}(y_i-\bar{y})^2. \quad (34)$$

The regression sum of squares was calculated as

$$SSR = \sum_{i=1}^{n_f}(\hat{y}_i-\bar{y})^2. \quad (35)$$

The total variation was decomposed according to

$$SST = SSR + SSE. \quad (36)$$

The adjusted coefficient of determination was calculated as

$$\overline{R}^2 = 1 - \left(\frac{n_f-1}{n_f-p-1}\right)\left(1-R^2\right), \quad (37)$$

where p represented the number of explanatory variables.

2.1.0. 3.Analysis of variance

The overall regression significance was evaluated using the F statistic:

$$F = \frac{SSR/p}{SSE/(n_f-p-1)}. \quad (38)$$

The F statistic assessed whether the explanatory variables jointly accounted for statistically detectable variation in the dependent construct.

2.10.4. Regression coefficient significance

For each regression coefficient, the t statistic was calculated as

$$t_j = \frac{\hat{\beta}_j}{SE(\hat{\beta}_j)}. \quad (39)$$

The estimated variance–covariance matrix of the regression coefficients was represented as

$$Var(\hat{\beta}) = \hat{\sigma}^2\left(X^TX\right)^{-1}, \quad (40)$$

where

$$\hat{\sigma}^2 = \frac{SSE}{n_f-p-1}. \quad (41)$$

The standard error of each coefficient was obtained from the corresponding diagonal element of the variance–covariance matrix.

The 95% confidence interval for a regression coefficient was calculated as

$$CI_j = \hat{\beta}_j \pm t_{\alpha/2,n_f-p-1}SE(\hat{\beta}_j). \quad (42)$$

The statistical significance level was set at

$$\alpha = 0.05.$$

The null hypothesis for an individual regression coefficient was formulated as

$$H_0{:}\beta_j = 0, \quad (43)$$

while the alternative hypothesis was expressed as

$$H_1 : \beta_j \neq 0. \quad (44)$$

A probability value of $p<0.05$ was interpreted as evidence of a statistically detectable association under the specified model.

2.10.5. Standardized regression coefficients

For comparison of regression coefficients measured on different scales, standardized coefficients were calculated as

$$\beta_j^* = \hat{\beta}_j\frac{s_{X_j}}{s_Y}, \quad (45)$$

where s_{X_j} represented the standard deviation of analyst j and s_Y represented the standard deviation of the dependent variable.

The standardized coefficient represented the standardized change in the dependent construct associated with a one-standard-deviation difference in the corresponding analyst, conditional on the other variables in the model.

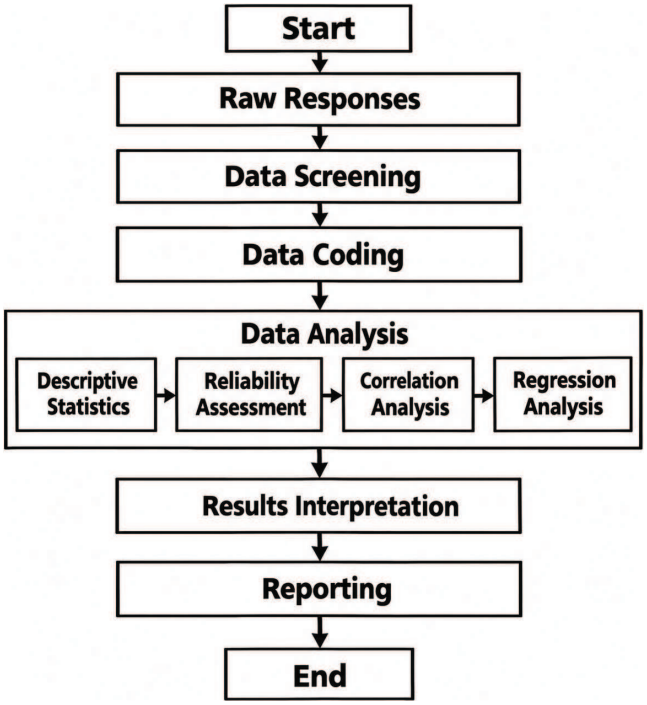
2.11. Data analysis procedure

The data analysis process started with gathering 427 questionnaires and keeping 420 valid responses for analysis. The collected data were subjected to cleaning, coding, and structuring. Descriptive statistics was performed through frequencies, percentage, mean, and standard deviation to give a summary of the collected data. Cronbach's alpha test was used to measure the internal consistency of the measured constructs.

The algorithmic flow is illustrated in Figure 2.

Pearson correlation analysis was done to measure the correlation between ICTI, EC, and SUD. Regression analysis was finally performed using IBM SPSS Statistics Version 29.

Figure 2
Analytical sequence for data processing and statistical analysis



2.12. Ethical considerations

Ethical clearance was obtained from the concerned authority before conducting data collection. The nature and scope of the study were made clear to the participants before filling out the questionnaire. Participants had the choice not to take part in the study. They were asked for their informed consent before being told of their right to opt out from the study. Anonymity and confidentiality were assured throughout the whole process of data collection and analysis.

3. Results and Discussion

Results of the survey conducted through the questionnaire as well as statistical analysis of the data collected are provided below in this section. Results are presented in the form of tables and are intended to be easily interpreted and compared with other sources of literature. The use of descriptive and inferential statistics is applied in the analysis of the relationship between the ICTI in EC and sustainability of urban development in Ekiti State, Nigeria.

The demographic information of the participants is represented in Table 6. As can be seen from the table, 54.3% of the total respondents were males, whereas 45.7% of the total respondents were females. The largest group of respondents were students constituting 53.6% of the total number, followed by lecturers (22.9%), teachers (12.9%), and ICT staff (10.7%). It is evident from the above table that the respondents were evenly distributed among the five selected areas of study, including Ado-Ekiti, Oye-Ekiti, Ikere-Ekiti, Ikole-Ekiti, and Ijero-Ekiti.

This is a reflection of the fact that respondents belonged to all stakeholder groups concerned in EC. The highest number were students (53.6%), followed by lecturers (22.9%), teachers (12.9%), and ICT personnel (10.7%). The sampling was spread throughout the five chosen towns ensuring good geographic diversity, which enhanced the reliability and validity of the results.

As seen from Table 7, the availability of ICTI at the selected educational institutions had the grand mean value of 3.78, which means that there is quite a good deployment of ICTI in the institutions. Internet connection (Mean = 4.18), computer labs (Mean = 3.94), wireless network (Mean = 3.88), and digital library facilities (Mean = 3.82) received high scores. On the other hand, electricity reliability (Mean = 3.11) had the lowest score, implying that electricity unreliability is one of the main barriers to ICT use. The obtained results are in line with the findings of Fakunle and Ajani [1] and Osiesi et al. [6] about insufficient infrastructure and electricity reliability as important obstacles to ICT usage in Nigerian education.

It was discovered that there was an adequate infrastructure of ICT (Grand Mean = 3.78). The highest scores were recorded for internet connectivity, computer laboratories, and digital library

Table 6
Demographic characteristics of respondents (n = 420)

Variable	Category	Frequency	Percentage (%)
Gender	Male	228	54.3
	Female	192	45.7
Age	18–25	146	34.8
	26–35	118	28.1
	36–45	89	21.2
	Above 45	67	15.9
Respondent Category	Students	225	53.6
	Lecturers	96	22.9
	Teachers	54	12.9
	ICT Staff	45	10.7
Study Area	Ado-Ekiti	110	26.2
	Oye-Ekiti	92	21.9
	Ikere-Ekiti	80	19.0
	Ikole-Ekiti	70	16.7
	Ijero-Ekiti	68	16.2

Table 7
Availability of ICT infrastructure

ICT Infrastructure Parameter	Mean	SD	Decision
Internet connectivity	4.18	0.73	High
Computer laboratories	3.94	0.81	High
Wireless network availability	3.88	0.86	High
Multimedia classrooms	3.75	0.79	Moderate
Digital library facilities	3.82	0.77	High
Electricity reliability	3.11	0.95	Moderate

Source: Field Survey (2026)
Grand Mean = 3.78

facilities. However, electricity was the least mean score of the components. From the findings, it is clear that inadequate power availability is the major factor hampering effective use of ICT. The findings support the research findings of Fakunle and Ajani [1] and Osiesi et al. [6].

Table 8 indicates efficiency in EC as a result of using ICT. It can be noted from the findings that there was very high efficiency in EC since the grand mean was 4.17. Information distribution (Mean = 4.29) and lecturer–student communication (Mean = 4.26) were the highly rated components, while digital classroom communication (Mean = 4.13), online assignment submission (Mean = 4.11), and academic collaboration (Mean = 4.08) were the other components, respectively. It can be seen that there was very high efficiency in communication when there were better ICT facilities in educational institutions. The findings corroborate those of Hafa and Moubtassime [3], Hailegebreal et al. [4], and Adebanjo et al. [7].

Table 8
Effectiveness of educational communication

Communication Indicator	Mean	SD
Lecturer–student communication	4.26	0.69
Online assignment submission	4.11	0.72
Information dissemination	4.29	0.66
Academic collaboration	4.08	0.71
Digital classroom interaction	4.13	0.75

Grand Mean = 4.17

It turned out that the use of EC proved to be quite effective in institutions equipped with proper ICTI. According to the opinion of the respondents, there was an evident improvement in communication between lecturers and students, information transfer, cooperation, and educational engagement because of the implementation of digital communication means. The findings coincide with those obtained by Adebanjo et al. [7], Hafa and Moubtassime [3], and Hailegebreal et al. [4].

Table 9 shows that there is a statistically significant positive relationship between ICTI and EC. Within the developed model, there is a correlation coefficient (R = 0.846), which suggests the existence of a strong positive relationship between the two variables. There is 71.6% of variance in EC, which can be explained by the impact of ICTI. In addition, the standardized regression coefficient (β = 0.846) and t-value = 32.44, meaning that there is an association between improvement in higher ICTI scores and the effectiveness of communication in education. This finding matches those made by Okundaye et al. [2], Ajibade and Zaidi [8], and Eze et al. [16].

Table 9
Regression analysis demonstrating the relationship between ICT infrastructure on communication for education

Variable	β	t-value	p-value
ICT infrastructure	0.846	32.44	<0.001
Model Statistics		Value	
R		0.846	
R^2		0.716	
F-value		1053.83	

The relationship between ICTI and EC was found to be positive and high (R = 0.846). Coefficient of determination (R^2 = 0.716) indicated that 71.6% of the variance in EC was explained by ICTI. Standardized regression coefficient (β = 0.846) indicated that there is a strong contribution from ICTI to the efficiency of communication in educational institutions. The result agrees with the findings of Okundaye et al. [2], Ajibade & Zaidi [8], and Eze et al. [15] on ICTI and communication efficiency correlation.

Table 10 shows the contribution of EC supported by ICTI to SUD. The improvement in the quality of education (Mean = 4.33) is ranked first among the indicators considered in the study, followed by human capital development (Mean = 4.28), digital inclusion (Mean = 4.16), knowledge sharing (Mean = 4.11), institutional efficiency (Mean = 4.07), and contribution to smart governance (Mean = 3.98). From the results above, it is clear that the respondents view ICTI to be an important is statistically related to SUD due to its contributions to EC. This result is in line with the findings of Ruth et al. [14], and Nwoke et al. [21].

Table 10
Contribution of ICT infrastructure to sustainable urban development

Urban Development Indicator	Mean	Rank
Improved educational quality	4.33	1
Human capital development	4.28	2
Digital inclusion	4.16	3
Knowledge sharing	4.11	4
Institutional efficiency	4.07	5
Smart governance support	3.98	6

The obtained results indicated the high level of approval of participants regarding the fact that ICT-based EC greatly contributes to sustainable development of cities. The best contribution was found in the quality of education, followed by the development of human capital and digitalization. From the conducted research, one may conclude that EC is one of the essential channels through which ICTI contributes to sustainability in urban areas. The research findings confirm the results presented by Ruth et al. [14] and Nwoke et al. [21].

3.1. Validation of results

Validity and reliability of empirical findings were further analyzed based on the findings obtained during the statistical analysis provided in Table 4. The questionnaire proved to be very reliable due to high levels of internal consistency measured as 0.91 according to the value of Cronbach's alpha that exceeds the recommended minimum value of 0.70. Furthermore, regression is significant (F = 1053.83), which indicates the capacity of ICTI to corresponds with EC. The diagnostics showed appropriate values of multicollinearity (variance inflation factor < 2.0) and normally distributed residuals, which satisfy the assumptions of linear regression. Hence, the regression model provided in Table 4 proves to be valid and reliable enough for analyzing the influence of ICTIs on EC.

In conclusion, the findings provided in Tables 2–5 show that ICTI significantly shows a positive association with the level of EC and helps achieve SUD in Ado-Ekiti, Ikere-Ekiti, Ijero-Ekiti, Oye-Ekiti, and Ikole-Ekiti. Educational institutions having higher levels of internet connection, computerization, and communication facilities are associated with communication among lecturers and students, improved collaboration, and improved overall functioning. Therefore, the present study supports the previous research conclusions [2, 7, 14, 21, 23].

3.2. Discussion

Results show that ICTI substantially affects EC and has substantial implications for SUD in Ekiti State, Nigeria. The relatively high value of availability of internet, digital libraries, and means of communication indicates that institutions with sufficient ICTI experience better communication between lecturers and students, information flow, cooperation, and learning interaction. However, the lack of electricity and network problems play an essential role in hindering the efficient use of ICTI.

Based on the results of the regression analysis, there is a positive correlation between ICTI and EC with R^2 of 0.716 (what means that ICTI accounts for 71.6% of the variance in EC). Results highlight the importance of ICTI as one of the most significant factors of effective EC and ICT-based education process. Relatively high value of the explanatory power of the model demonstrates that the improvement of ICTI can be very helpful in order to improve the quality of EC; however, taking into account the cross-sectional nature of the research, this result can be considered only as an empirical association. With regard to practical implications, the inference from the findings is that development of ICTI at educational institutions may have importance for the development of the context within which EC is conducted. The findings could assist educational managers, infrastructure developers, and policymakers identify infrastructure limitations, which affect digital information sharing and educational engagement. However, given the nature of this study being cross-sectional and perception based, the implications of this study should not be taken as proof of any causation, but rather indication of relationships.

The findings are consistent with the findings of Fakunle and Ajani [1], Hailegebreal et al. [4], Adebanjo et al. [7], and Ajibade and Zaidi [8] who found out that ICTI sufficiency was linked with good communication, ICT usage, and education engagement. Additionally, the findings are consistent with the results of Ruth et al. [14] and Nwoke et al. [21] on the importance of digital infrastructure in human capital development and inclusive education.

3.3. Novel contributions and implications

3.3.1. Novel contributions

1) An empirical institutional model that studies the correlation between ICTI and EC in the context of SUD in Ekiti State, Nigeria.
2) Multi-location empirical data from different educational centers such as Ado-Ekiti, Oye-Ekiti, Ikere-Ekiti, Ikole-Ekiti, and Ijero-Ekiti thus expanding empirical data collection from a one-institution setting.
3) The inclusion of various stakeholders from the educational process including students, lecturers, teachers, and ICT specialists.
4) Measurement of the ICTI-EC correlation showing strong positive correlation (R = 0.846, R^2 = 0.716, F = 1053.83).
5) The identification of the infrastructure constraints especially with regard to electricity availability in conjunction with better availability of connectivity and digital ICTI.
6) The creation of an empirical basis for the future verification of the research results through the longitudinal research, stakeholder analysis, and measurement of the network performance and connectivity.

3.3.2. Practical and policy implications

When it comes to institutions of education, investments made in infrastructure should focus not only on the bandwidth capacity of the internet but also on wireless connectivity, computing resources, digital libraries, and power supply. Where policy makers are concerned, infrastructure investment programs should be structured in a manner such that urban and semi-urban educational institutions are included in the program and not restricted to major institutions alone. ICT planning within the institutions should take into account infrastructure investments in addition to other aspects.

3.3.3. Limitations of the study

The research was also limited in several ways. For one, its cross-sectional design limited its ability to draw causative inferences from the results obtained because it could only determine association between the variables. Self-reported data might have posed problems through common method variance and self-report bias. Respondent heterogeneity could be a problem because the survey involved students, lecturers, teachers, and ICT personnel whose experiences and perceptions differed. Geographically, the study was limited to five educational centers in Ekiti State. Moreover, direct performance metrics such as signal strength, throughput, latency, packet loss, uptime, coverage, and spectrum quality were not used. The survey also took place at a certain period of time when connectivity and power supply was available.

4. Conclusion

The ICTI is highly associated with education communication and can be used in facilitating SUD in Ekiti State, Nigeria. The findings indicate that educational institutions sampled in this study have access to ICT facilities such as internet, computer labs, wireless network, and digital learning material. However, the main constraint in accessing sustainable ICT is the electricity reliability. From the empirical findings, a very strong and

highly significant positive association exists between ICTI and EC (R = 0.846, R^2 = 0.716, F = 1053.83). These findings reveal that there is strong connection between ICTI and EC within sampled institutions. Therefore, ICTI can facilitate lecturer–student communication, information sharing, collaboration, e-learning, and digital classroom. ICT-enabled EC is viewed as a tool for SUD through education quality improvement, human capital development, digital divide reduction, knowledge sharing, institutional effectiveness, and smart governance by the sampled respondents. Nevertheless, the constraint of electricity reliability, inequitable access, and ICT usage disparity may prevent the full realization of ICT-enabled EC. Conclusively, enhanced ICTI, electricity provision, and accessibility may enhance communication in education and facilitate the realization of sustainable development goals within the education sector in Ekiti State. However, bearing in mind that the research adopted a cross-sectional and perception-based methodology, the findings show a link but not linked with relationship. It is therefore suggested that further studies adopt a more complex design.

Recommendations

There is need to enhance ICTI, internet connectivity, ICT learning facilities, and electricity supply. The training of digital literacy should be conducted continuously to both the students, lecturers, teachers, and ICT professionals. There is need for policymakers to facilitate equal distribution of ICT in urban and semi-urban regions, while more research should involve a larger sample size to incorporate ICTs like artificial intelligence, cloud computing, and Internet of Things.

Limitations and Future Studies

There are a number of shortcomings with the current study. To begin with, being cross-sectional in design, involving perceptual measures and the geographical setting limited to some schools in Ekiti state makes it impossible to draw any conclusions about causation and generalizations. Heterogeneous Respondents: In this study, students, lecturers, teachers, and ICT staff members were used as respondents. They could possibly differ in terms of exposure to ICT and education communication infrastructures. Although the aggregate is consistent with the organizational context of this study, heterogeneous respondents can influence the aggregate relationships. Subgroup analysis should be done in future research for different types of respondents. In addition, no information was collected about network performance measures such as throughput, latency, coverage and reliability. Thus, future research should adopt a longitudinal and mixed-methods approach, gather objective data on network performance metrics, and examine other new ICT such as artificial intelligence, cloud computing, and Internet of Things.

Ethical Statement

This study was reviewed by the Federal University Oye-Ekiti, Nigeria, and formal ethical approval was not required in accordance with the institution's regulations.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

Data are available from the corresponding author upon reasonable request.

Author Contribution Statement

Olarewaju Peter Ayeoribe: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Olaitan Akinsanmi:** Supervision, Project administration. **Adebimpe O. Esan:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Supervision. **Bolaji A. Omodunbi:** Supervision, Project administration. **Ayodele S. Oluwole:** Formal analysis, Investigation, Resources. **Olumayowa A. Ojo:** Formal analysis, Investigation, Resources.

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