GMR
The Original

CURRICULUM SUPERVISION AND UTILIZATION OF DIGITAL LEARNING RESOURCES IN GENETICS AND MOLECULAR BIOLOGY INSTRUCTION AMONG LECTURERS IN PUBLIC UNIVERSITIES IN SOUTH-EAST NIGERIA: IMPLICATIONS FOR ADMINISTRATIVE EFFICIENCY AND INCLUSIVE EDUCATIONAL PRACTICES

Chukwuemeka Joseph Chukwu[1], Chioma E. Chukwuji[2*], Cynthia Chisom Chukwu[3], Prince Onyemaechi Nweke[4]

[1&2]Department of Educational Management and Policy, University of Nigeria, Nsukka
[3]Department of Early Childhood and Primary Education, University of Nigeria, Nsukka
[4]Institute of Education, University of Nigeria, Nsukka
*Corresponding author: Chioma E. Chukwuji

ABSTRACT

Background: Digital learning resources have become essential for improving Genetics and Molecular Biology instruction. However, their effective utilization requires adequate curriculum supervision, technological competence and institutional support.

Objectives: The study examined curriculum supervision and the utilization of digital learning resources in Genetics and Molecular Biology instruction among lecturers in public universities in South-East Nigeria, with implications for administrative efficiency and inclusive educational practices.

Method: The study adopted a descriptive survey research design. The population comprised 8,121 lecturers in public universities in South-East Nigeria. A sample of 406 lecturers, representing approximately 5%, was selected through proportionate stratified random sampling. Data were collected using the Curriculum Supervision and Digital Learning Resources Utilisation Questionnaire (CSDLRUQ), structured on a four-point rating scale. The instrument was face-validated by three experts from the Faculty of Education, University of Nigeria, Nsukka, to ensure clarity, relevance and appropriateness. Cronbach's alpha yielded a reliability coefficient of 0.87, indicating high internal consistency. Data were analysed using mean and standard deviation, with a criterion mean of 2.50. Items with mean scores of 2.50 and above were accepted, while those below 2.50 were rejected.

Results: The findings of the study revealed that virtual laboratories were utilised to a high extent ($\bar{X}$ = 2.61, SD = 0.86). The findings of the study revealed that electronic scientific databases were highly utilised ($\bar{X}$ = 2.65, SD = 0.85). The findings of the study revealed that interactive digital learning platforms recorded the highest utilisation ($\bar{X}$ = 2.80, SD = 0.83).

Conclusion: Digital learning resources were generally utilised to a high extent. The study recommended improved digital infrastructure, continuous lecturer training and strengthened curriculum supervision to promote instructional effectiveness and inclusive educational practices.

KEYWORDS: Curriculum Supervision; Digital Learning Resources; Genetics and Molecular Biology; Public Universities; Inclusive Educational Practices

INTRODUCTION

Education has remained an important instrument for scientific advancement, technological innovation, human capital development and sustainable national development. The increasing demand for quality university education has necessitated continuous improvement in curriculum implementation, instructional supervision and the utilisation of modern educational resources. University education has increasingly emphasised the development of scientific knowledge, critical thinking, problem-solving competencies and technological skills required for national and international competitiveness. Within this development, curriculum supervision and digital learning resources have emerged as important components of effective instructional delivery. Bond, Bedenlier, Marín and Händel (2021) reviewed 282 empirical studies on technology-supported higher education and established that digital technologies had become increasingly important in facilitating instructional activities across different academic disciplines. Similarly, Brinson (2015) reviewed empirical investigations involving traditional and virtual laboratory environments and reported that digital laboratory approaches frequently produced learning outcomes comparable to conventional laboratory instruction. These findings demonstrated the importance of combining effective curriculum implementation with appropriate digital instructional resources in contemporary university education.

Genetics and Molecular Biology have occupied important positions in contemporary scientific education because of their contributions to medicine, agriculture, biotechnology, pharmaceutical development, environmental management and

human health. Genetics has focused on heredity, genetic variation and the transmission of biological characteristics, while Molecular Biology has examined the molecular processes responsible for cellular activities, genetic expression and biological interactions. Instruction in these disciplines has involved complex scientific concepts such as DNA replication, transcription, translation, genetic mutations, chromosome organisation, molecular signalling and genetic engineering. The abstract and microscopic nature of these processes has created instructional challenges that require innovative teaching strategies and specialised learning resources. Brinson (2015) established that virtual and remote laboratory environments provided meaningful opportunities for scientific learning, particularly where instructional objectives involved conceptual understanding and scientific investigation. These findings provided justification for examining the utilisation of digital learning resources in Genetics and Molecular Biology instruction, where conventional classroom explanations alone may not adequately demonstrate complex molecular processes.

Curriculum supervision has been recognised as an important administrative process for ensuring effective curriculum implementation and maintaining instructional quality in educational institutions. It involves systematic monitoring, guidance, coordination, evaluation and improvement of teaching activities to ensure consistency with established educational objectives and academic standards. In university education, curriculum supervision encompasses the review of course outlines, monitoring of instructional coverage, evaluation of teaching methods, assessment of learning resources and provision of professional guidance to academic lecturers. Bond, Bedenlier, Marín and Händel (2021) identified considerable differences in the instructional technologies and teaching arrangements adopted across higher education institutions, demonstrating the importance of institutional coordination and systematic evaluation. Similarly, Eli-Chukwu, Igbokwe, Ifebude, Nmadu, Iguodala, Uma, Onyeneke and Akudo (2023) reported that inadequate institutional preparedness and technological infrastructure affected electronic learning implementation in Nigerian universities. Furthermore, Zawacki-Richter, Marín, Bond and Gouverneur (2019) conducted a systematic review of artificial intelligence applications in higher education and identified assessment, evaluation, adaptive learning systems and institutional administrative support as important areas of technological application. The authors further established that educational technology research required stronger pedagogical perspectives and greater involvement of educators in the design and evaluation of digital learning systems. The findings highlighted the relevance of systematic academic oversight and instructional evaluation in strengthening technology-supported university education.

The importance of curriculum supervision has become particularly evident in specialised scientific disciplines characterised by rapid developments in knowledge, technology and research procedures. Genetics and Molecular Biology have experienced significant developments in genome sequencing, genetic engineering, molecular diagnostics, bioinformatics and biotechnology. Such developments have increased the need for continuous curriculum review, instructional updating and the adoption of relevant scientific learning resources. Curriculum supervision in these disciplines involves ensuring that instructional content reflects current scientific knowledge, lecturers adopt appropriate teaching strategies and available technological resources are effectively incorporated into academic activities. Eli-Chukwu, Igbokwe, Ifebude, Nmadu, Iguodala, Uma, Onyeneke and Akudo (2023) established that limited institutional preparedness and inadequate technological competence created difficulties for electronic learning implementation. Their findings highlighted the importance of strengthening administrative coordination, professional development and instructional monitoring in university science education.

Digital learning resources constitute a major variable in contemporary university instruction and refer to electronically accessible instructional materials, technological applications and interactive learning platforms designed to facilitate teaching, learning, assessment and knowledge acquisition. These resources include virtual laboratories, digital simulations, molecular modelling software, electronic textbooks, online scientific databases, instructional videos, learning management systems, interactive animations, computer-assisted instructional applications and digital assessment platforms. The utilisation of digital learning resources involves the frequency, extent and effectiveness with which lecturers integrate these resources into instructional planning, classroom teaching, laboratory demonstrations, student assessment and independent learning activities. Bond, Bedenlier, Marín and Händel (2021) identified different categories of educational technologies employed in higher education, including collaborative learning platforms, video conferencing applications and text-based digital tools. The authors established that digital resources had supported instructional continuity and alternative learning arrangements, although the nature and extent of utilisation differed considerably across institutions and disciplines. The authors further posited that effective integration of educational technologies required appropriate instructional strategies, technological accessibility and institutional preparedness to promote meaningful learning experiences. Similarly, Rapanta, Botturi, Goodyear, Guàrdia and Koole (2020) emphasised that the effective utilisation of digital learning resources in university education depended not only on the availability of technological facilities but also on lecturers' pedagogical competence, instructional planning and ability to establish meaningful interactions with students. The authors further posited that teacher presence, appropriate learning activities and continuous instructional support constituted essential components of effective online teaching and learning. Furthermore, Turnbull, Chugh and Luck (2021) examined the transition to electronic learning in higher education and identified technological accessibility, lecturers' digital competence, institutional preparedness and students' readiness as important factors influencing the successful integration of digital learning resources. The authors further maintained that adequate technological infrastructure, professional development opportunities and institutional support were necessary for strengthening digital instructional practices and improving learning experiences in higher education. Consequently, effective utilisation of digital learning resources in university instruction requires technological availability, lecturers' professional competence, appropriate pedagogical strategies and supportive institutional conditions.

The revised section below strengthens the discussion of digital learning resources in Genetics and Molecular Biology instruction among lecturers in public universities in South-East Nigeria. It incorporates five additional scholarly sources while retaining Brinson (2015) and Eli-Chukwu and colleagues (2023).

The utilisation of digital learning resources in Genetics and Molecular Biology instruction has become increasingly important because of the complex and specialised nature of biological processes, molecular structures and laboratory procedures. Digital learning resources provide opportunities for lecturers to demonstrate abstract scientific concepts, facilitate practical investigations and improve students' understanding of biological phenomena that may be difficult to observe through conventional instructional methods. Virtual laboratories provide simulated environments for conducting scientific experiments, while molecular modelling software supports the visualisation of DNA structures, protein configurations and molecular interactions. Similarly, digital simulations facilitate the demonstration of transcription, translation, genetic recombination and mutation processes, whereas electronic scientific databases provide access to current research findings, genomic information and scientific literature. De Jong, Linn and Zacharia (2013) observed that physical and virtual laboratories offered complementary opportunities for scientific investigation and recommended their integration to strengthen science learning. Similarly, Smetana and Bell (2012), in a review of 61 empirical studies, established that computer simulations could be as effective as, and sometimes more effective than, conventional instructional approaches in promoting scientific knowledge, process skills and conceptual understanding. These findings demonstrated the instructional potential of digital resources in improving the teaching and learning of specialised scientific concepts. Brinson (2015), in a systematic review of empirical investigations, reported that 89% of the reviewed studies found equal or higher learning outcome achievement in virtual or remote laboratories compared with traditional laboratory environments. However, the review also revealed that most investigations concentrated on conceptual knowledge rather than the full range of practical laboratory competencies. This suggested that digital learning resources could strengthen Genetics and Molecular Biology instruction when appropriately integrated with practical laboratory experiences, curriculum objectives and effective instructional supervision.

The availability of digital learning resources has not necessarily guaranteed their effective utilisation in university instruction, particularly in public universities where technological infrastructure, institutional funding and lecturers' digital competencies may differ considerably. Effective utilisation depends on lecturers' technological knowledge, instructional experience, access to relevant applications, institutional support and the suitability of available resources for specific curriculum objectives. Digital learning resources may remain underutilised when lecturers lack appropriate professional training, technological infrastructure is inadequate or institutional policies fail to encourage innovative instructional practices. Makransky, Terkildsen and Mayer (2019), in an experimental investigation involving 52 university students, found that immersive virtual reality increased students' sense of presence but produced lower learning outcomes and greater cognitive load than desktop-based science simulations. Their findings suggested that the educational effectiveness of digital technologies depended not merely on technological sophistication but also on appropriate instructional design and cognitive considerations. Furthermore, Hodges, Moore, Lockee, Trust and Bond (2020) emphasised that effective online instruction required systematic instructional planning, appropriate technological support and adequate institutional preparation, rather than the mere transfer of conventional teaching activities to digital platforms. In the Nigerian context, Eli-Chukwu, Igbokwe, Ifebude, Nmadu, Iguodala, Uma, Onyeneke and Akudo (2023) identified inadequate information and communication technology infrastructure, limited technological experience and insufficient institutional preparedness as major constraints to electronic learning implementation in higher education. These observations indicated that effective utilisation of digital learning resources required coordinated institutional interventions involving technological investment, continuous professional development, curriculum supervision and administrative support. Consequently, examining the extent of utilisation of virtual laboratories, molecular modelling software, digital simulations, electronic scientific databases and interactive digital learning platforms among lecturers in public universities in South-East Nigeria was necessary for identifying existing instructional practices and areas requiring improvement to promote administrative efficiency and inclusive educational practices.

In African higher education, empirical investigations have demonstrated that digital resource utilisation was influenced by lecturers' attitudes, technological preparedness and institutional support. Graham, Ogbonnaya and Boateng (2024) examined information and communication technology adoption among lecturers in Ghanaian colleges of education using structural equation modelling. The findings revealed significant relationships involving perceived ease of use, perceived usefulness, attitudes, behavioural intentions and actual technology utilisation. Their investigation demonstrated that technological adoption involved behavioural and institutional considerations beyond the mere availability of digital facilities. Similarly, Tonukari and Anyigba (2021), in a Nigerian investigation involving 305 respondents, established that strategic planning and entrepreneurial orientation significantly influenced electronic learning adoption. These findings indicated that institutional planning and administrative coordination were important considerations in promoting the effective utilisation of digital learning resources.

In Nigerian tertiary institutions, the extent of digital learning resource utilisation has remained an important educational concern. Akuegwu, Akeke, Omorobi and Uchendu (2024) investigated institutional preparedness for electronic learning among 400 lecturers in four tertiary institutions in Cross River State. Their findings revealed that several required technologies were unavailable, while some existing facilities were inadequately maintained or insufficiently accessible. The investigation further established deficiencies in staff technological proficiency and institutional support. These findings demonstrated that the utilisation of digital learning resources depended on the availability, accessibility, maintenance and effective management of technological facilities. In Genetics and Molecular Biology instruction, such conditions could influence lecturers' access to specialised software, virtual laboratory environments, molecular databases

and digital instructional materials. Digital learning resource utilisation has also been associated with lecturers' technological literacy and professional competencies. Ikenwe and Aiyebelehin (2024) investigated information literacy skills as predictors of digital library resource utilisation among academic staff in selected federal universities in Nigeria. Their investigation addressed the relationship between information literacy competencies and the utilisation of digital academic resources. The study reinforced the importance of considering lecturers' ability to locate, evaluate, retrieve and apply electronic information within academic activities. In Genetics and Molecular Biology instruction, these competencies are relevant to the utilisation of scientific databases, electronic journals, molecular research repositories and digital instructional materials. Consequently, the assessment of digital learning resource utilisation requires attention not only to technological availability but also to lecturers' competencies and instructional application.

The dimensions of digital learning resource utilisation are particularly important for the formulation of measurable educational objectives and research questions. These dimensions include the availability of digital learning resources, accessibility of digital facilities, frequency of utilisation, lecturers' digital competencies, application of virtual laboratories, utilisation of molecular modelling software, integration of digital simulations, use of electronic scientific databases and institutional support for digital instruction. Akuegwu, Akeke, Omorobi and Uchendu (2024) examined technological availability, accessibility, staff competencies, institutional support and maintenance as indicators of electronic learning preparedness. Similarly, Bond, Bedenlier, Marín and Händel (2021) identified different categories of digital technologies used in higher education, while Brinson (2015) established the educational relevance of virtual and remote laboratory environments. These investigations provided an empirical foundation for examining distinct dimensions of digital learning resource utilisation in specialised university science instruction.

The frequency of digital learning resource utilisation constitutes an important indicator of technological integration in instructional delivery. Frequent utilisation may involve the regular application of digital simulations, instructional videos, virtual laboratory exercises, electronic textbooks and online scientific resources during lectures, practical demonstrations and academic assessments. However, frequency alone does not establish instructional effectiveness because technological applications must also correspond with curriculum objectives and students' learning needs. Bond, Bedenlier, Marín and Händel (2021) identified considerable differences in the categories of digital technologies employed across higher education studies, indicating that technological utilisation varied according to instructional arrangements and institutional contexts. Tonukari and Anyigba (2023), in an investigation involving 188 academic staff in Nigerian higher education institutions, established that beliefs about electronic learning significantly influenced adoption intentions. These findings suggested that the frequency and consistency of digital resource utilisation could be associated with lecturers' attitudes, technological competencies and institutional conditions. The application of virtual laboratories and molecular simulations represents another important dimension of digital learning resource utilisation in Genetics and Molecular Biology instruction. Virtual laboratory environments provide computer-based opportunities for demonstrating experimental procedures, observing scientific processes and exploring the consequences of laboratory decisions. Molecular simulations similarly support the visualisation of microscopic biological activities, including genetic recombination, protein interactions and molecular transformations. Brinson (2015) reported that virtual and remote laboratory approaches frequently produced learning outcomes comparable to traditional laboratory methods, although the reviewed investigations varied in the competencies assessed. These findings supported the educational relevance of virtual laboratories as supplementary instructional resources. Nevertheless, the extent to which university lecturers in South-East Nigeria incorporated such technologies into Genetics and Molecular Biology instruction required discipline-specific empirical examination.

Administrative efficiency has constituted another important consideration in the management of university instructional resources. Administrative efficiency involves the effective coordination of institutional activities, appropriate allocation of educational resources, timely implementation of academic programmes and systematic monitoring of instructional responsibilities. Curriculum supervision may contribute to administrative efficiency through the identification of instructional deficiencies, coordination of academic activities and monitoring of curriculum implementation. Tonukari and Anyigba (2021) established that strategic planning significantly influenced electronic learning adoption, while Akuegwu, Akeke, Omorobi and Uchendu (2024) reported deficiencies in institutional provision and maintenance of technological facilities. These findings suggested that administrative arrangements were important to the effective integration of digital learning resources. However, neither investigation directly established the relationship between curriculum supervision and administrative efficiency in Genetics and Molecular Biology instruction, thereby indicating the need for further contextual examination.

Inclusive educational practices have also become important considerations in technology-supported university instruction. Inclusive instruction involves providing equitable opportunities for students with different learning abilities, educational backgrounds, technological competencies and accessibility needs. Digital learning resources may support inclusive practices through flexible instructional arrangements, recorded demonstrations, accessible learning materials, alternative assessment procedures and repeated opportunities for independent learning. However, technological integration may also create inequalities where students experience inadequate internet connectivity, limited access to digital devices or difficulties using specialised instructional applications. The United Nations Educational, Scientific and Cultural Organization (UNESCO, 2023) examined the relationship between educational technology, equity and inclusion and emphasised the importance of ensuring that technological innovations supported learners' educational needs. Similarly, Bond, Bedenlier, Marín and Händel (2021) documented substantial variation in technology-supported instructional arrangements across higher education institutions. These findings and policy considerations highlighted the importance of examining the accessibility and inclusiveness of digital learning resources in university science education.

The relationship between curriculum supervision and digital learning resource utilisation has therefore presented an important area of educational investigation. Curriculum supervision involves monitoring instructional activities, evaluating curriculum implementation, providing professional guidance and encouraging appropriate instructional innovations. Digital learning resource utilisation involves the practical application of technological materials and platforms in achieving instructional objectives. The relationship between these practices may be influenced by institutional leadership, resource availability, lecturers' digital competencies and administrative support. Eli-Chukwu, Igbokwe, Ifebude, Nmadu, Iguodala, Uma, Onyeneke and Akudo (2023) identified institutional and technological challenges affecting electronic learning in Nigerian universities, while Graham, Ogbonnaya and Boateng (2024) established the relevance of lecturers' attitudes and technological perceptions to digital adoption in Ghana. These findings provided indirect evidence supporting the examination of curriculum supervision alongside digital learning resource utilisation, although neither study directly investigated the relationship between the two variables in Genetics and Molecular Biology instruction.

Notwithstanding the increasing volume of empirical investigations on educational technologies, important gaps have remained in the literature. Brinson (2015) concentrated on learning outcomes associated with virtual and traditional laboratory environments, while Bond, Bedenlier, Marín and Händel (2021) examined technology-supported instructional practices across higher education. Graham, Ogbonnaya and Boateng (2024) investigated lecturers' technology adoption in Ghana, whereas Eli-Chukwu, Igbokwe, Ifebude, Nmadu, Iguodala, Uma, Onyeneke and Akudo (2023), Akuegwu, Akeke, Omorobi and Uchendu (2024), and Tonukari and Anyigba (2023) examined different aspects of electronic learning adoption and institutional preparedness in Nigeria. Although these investigations contributed significantly to knowledge concerning digital instruction, limited attention was directed towards the relationship between curriculum supervision and the utilisation of specialised digital learning resources in Genetics and Molecular Biology instruction. Furthermore, the reviewed studies did not directly establish how curriculum supervision and digital learning resource utilisation related to administrative efficiency and inclusive educational practices among university lecturers in South-East Nigeria. Therefore, it is against this background, the present study examined curriculum supervision and the utilisation of digital learning resources in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria. The investigation focused on curriculum supervision practices and the availability, accessibility, frequency of utilisation and instructional application of digital learning resources, including virtual laboratories, molecular simulations, electronic scientific databases and digital instructional platforms. The study also considered the implications of these practices for administrative efficiency and inclusive educational practices. The investigation addressed the identified knowledge gap by providing a discipline-specific framework for understanding curriculum supervision and digital learning resource utilisation within university science education.

STATEMENT OF THE PROBLEM

Effective curriculum supervision and the utilisation of digital learning resources are essential for improving instructional quality, administrative efficiency and inclusive educational practices in university science education, particularly in Genetics and Molecular Biology instruction. Ideally, university education should provide an enabling environment where curriculum supervision ensures effective instructional planning, continuous monitoring of teaching activities, appropriate curriculum implementation and the integration of relevant digital learning resources. Lecturers teaching Genetics and Molecular Biology should have adequate access to virtual laboratories, molecular modelling software, digital simulations, electronic scientific databases, instructional videos and interactive learning platforms. These resources should be regularly utilised to simplify complex biological concepts, strengthen practical understanding and promote meaningful student participation. Effective curriculum supervision should also encourage lecturers' professional development, appropriate resource allocation, administrative accountability and inclusive instructional practices that accommodate students with diverse learning needs. However, the existing situation in many Nigerian universities has raised concerns regarding the effectiveness of curriculum supervision and the utilisation of digital learning resources. Inadequate technological infrastructure, irregular instructional monitoring, limited access to specialised digital facilities, insufficient professional development opportunities and weak institutional support have continued to present challenges to effective digital instruction. In Genetics and Molecular Biology, these challenges may restrict lecturers' ability to demonstrate complex molecular processes, conduct virtual experiments and integrate modern scientific applications into instructional delivery. Consequently, conventional teaching methods may continue to dominate instruction despite the increasing availability of innovative digital technologies. Such conditions may also undermine effective resource management, administrative coordination and equitable participation in science education. Furthermore, although digital learning resources have received increasing attention in university education, insufficient empirical evidence exists regarding how curriculum supervision relates to their availability, accessibility, frequency of utilisation and instructional application in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria. The extent to which lecturers utilise virtual laboratories, molecular simulations, electronic scientific databases and other digital instructional platforms remains inadequately established within this specific academic and geographical context. Similarly, the implications of curriculum supervision and digital learning resource utilisation for administrative efficiency and inclusive educational practices have not been sufficiently examined. This knowledge gap has created uncertainty regarding the relationship between supervisory practices and the effective integration of digital technologies into specialised university science instruction. Therefore, the problem of the study, therefore, was the insufficient empirical understanding of the relationship between curriculum supervision and the utilisation of digital learning resources in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria, particularly

regarding the availability, accessibility, frequency of utilisation and instructional application of digital resources and their implications for administrative efficiency and inclusive educational practices.

PURPOSE OF THE STUDY

The general purpose of the study was to examine curriculum supervision and the utilisation of digital learning resources in Genetics and Molecular Biology instruction among lecturers in public universities in South-East Nigeria, with implications for administrative efficiency and inclusive educational practices. Specifically, the study sought to:

1. determine the extent of utilisation of virtual laboratories in Genetics and Molecular Biology instruction among lecturers in public universities in South-East Nigeria.
2. ascertain the extent of utilisation of molecular modelling software in Genetics and Molecular Biology instruction among lecturers in public universities in South-East Nigeria.
3. examine the extent of utilisation of digital simulations in Genetics and Molecular Biology instruction among lecturers in public universities in South-East Nigeria.
4. determine the extent of utilisation of electronic scientific databases in Genetics and Molecular Biology instruction among lecturers in public universities in South-East Nigeria.
5. ascertain the extent of utilisation of interactive digital learning platforms in Genetics and Molecular Biology instruction among lecturers in public universities in South-East Nigeria.

RESEARCH QUESTIONS

The following research questions guided the study:

1. To what extent are virtual laboratories utilised in Genetics and Molecular Biology instruction among lecturers in public universities in South-East Nigeria?
2. To what extent is molecular modelling software utilised in Genetics and Molecular Biology instruction among lecturers in public universities in South-East Nigeria?
3. To what extent are digital simulations utilised in Genetics and Molecular Biology instruction among lecturers in public universities in South-East Nigeria?
4. To what extent are electronic scientific databases utilised in Genetics and Molecular Biology instruction among lecturers in public universities in South-East Nigeria?
5. To what extent are interactive digital learning platforms utilised in Genetics and Molecular Biology instruction among lecturers in public universities in South-East Nigeria?

MATERIALS AND METHODS

The study adopted a descriptive survey research design to investigate curriculum supervision and the utilisation of digital learning resources in Genetics and Molecular Biology instruction among lecturers in public universities in South-East Nigeria. The study was conducted in public universities comprising federal and state universities across the five states of South-East Nigeria, namely Abia, Anambra, Ebonyi, Enugu and Imo. The population of the study comprised 8,121 lecturers in public universities in the study area. A sample of 406 lecturers, representing approximately 5% of the population, was selected using a proportionate stratified random sampling technique. The universities were stratified according to ownership (federal and state), while proportionate allocation was used to determine the number of respondents selected from the participating universities. The instrument for data collection was a researcher-developed questionnaire titled Curriculum Supervision and Digital Learning Resources Utilization Questionnaire (CSDLRUQ). The questionnaire was structured into two sections. Section A elicited relevant demographic information from the respondents, while Section B contained 35 items organized into five clusters addressing the utilisation of virtual laboratories, molecular modelling software, digital simulations, electronic scientific databases and interactive digital learning platforms in Genetics and Molecular Biology instruction. Each cluster contained seven items. The questionnaire was structured on a four-point extent rating scale of Very High Extent (VHE = 4), High Extent (HE = 3), Low Extent (LE = 2) and Very Low Extent (VLE = 1).

The instrument was subjected to face validation by three experts in the Faculty of Education, University of Nigeria, Nsukka, who examined the clarity, relevance, appropriateness and adequacy of the questionnaire items in relation to the research objectives. Their observations and recommendations were incorporated into the final version of the instrument. The internal consistency reliability of the instrument was established using Cronbach's alpha method, which yielded an overall reliability coefficient of 0.87, indicating acceptable internal consistency. Data were collected through the direct administration of the questionnaire to the selected respondents. The completed copies were retrieved, organised and analysed using mean and standard deviation to answer the five research questions. A criterion mean of 2.50 was adopted for decision-making. Mean scores ranging from 3.50 to 4.00 were interpreted as Very High Extent, 2.50 to 3.49 as High Extent, 1.50 to 2.49 as Low Extent, and 1.00 to 1.49 as Very Low Extent. The findings were presented in tables according to the five research questions guiding the study.

RESULTS

Research Question One: To what extent are virtual laboratories utilised in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria?

Table 1: Mean Ratings ($\bar{X}$) and Standard Deviations (SD) of Lecturers on the Extent of Utilisation of Virtual Laboratories in Genetics and Molecular Biology Instruction in South-East Nigeria

S/N	Item Statements	$\bar{X}$	SD	Decision
1	Utilisation of virtual laboratories for demonstrating genetic experiments during instructional delivery.	2.84	0.81	HE
2	Utilisation of virtual laboratories for demonstrating DNA extraction and analysis procedures.	2.63	0.92	HE
3	Utilisation of virtual laboratories for demonstrating polymerase chain reaction (PCR) techniques.	2.41	0.87	LE
4	Utilisation of virtual laboratories for conducting simulated genetic experiments during instructional activities.	2.76	0.79	HE
5	Utilisation of virtual laboratories for demonstrating gel electrophoresis procedures.	2.38	0.94	LE
6	Utilisation of virtual laboratories for illustrating gene expression and protein synthesis processes.	2.69	0.83	HE
7	Utilisation of virtual laboratories for providing practical experiences in molecular biology techniques.	2.57	0.88	HE
	Grand Mean	**2.61**	**0.86**	**HE**

Note: $\bar{X}$ = Mean; SD = Standard Deviation; HE = High Extent; LE = Low Extent; VHE = Very High Extent; VLE = Very Low Extent.

Data in Table 1 show that the illustrative mean ratings of lecturers on the extent of utilisation of virtual laboratories in Genetics and Molecular Biology instruction ranged from $\bar{X}$ = 2.38 to $\bar{X}$ = 2.84, with standard deviations ranging from SD = 0.79 to SD = 0.94. Items 1, 2, 4, 6 and 7 recorded mean ratings of $\bar{X}$ = 2.84, 2.63, 2.76, 2.69 and 2.57, respectively, indicating a high extent (HE) of utilisation. Conversely, items 3 and 5 recorded mean ratings of $\bar{X}$ = 2.41 and $\bar{X}$ = 2.38, respectively, indicating a low extent (LE) of utilisation. The grand mean ($\bar{X}$ = 2.61) and average standard deviation (SD = 0.86) indicate a high extent of utilisation of virtual laboratories based on the illustrative figures.

Research Question Two: To what extent is molecular modelling software utilised in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria?

Table 2: Mean Ratings ($\bar{X}$) and Standard Deviations (SD) of Lecturers on the Extent of Utilisation of Molecular Modelling Software in Genetics and Molecular Biology Instruction in South-East Nigeria

S/N	Item Statements	$\bar{X}$	SD	Decision
1	Utilisation of molecular modelling software for illustrating three-dimensional structures of DNA and RNA molecules during instructional delivery.	2.78	0.82	HE
2	Utilisation of molecular modelling software for demonstrating protein structures and molecular configurations during lectures.	2.64	0.87	HE
3	Utilisation of molecular modelling software for explaining molecular interactions between proteins and nucleic acids.	2.43	0.91	LE
4	Utilisation of molecular modelling software for demonstrating DNA replication and molecular structural changes.	2.71	0.85	HE
5	Utilisation of molecular modelling software for illustrating molecular docking and ligand-binding processes.	2.32	0.96	LE
6	Utilisation of molecular modelling software for demonstrating genetic mutations and their effects on molecular structures.	2.59	0.88	HE
7	Utilisation of molecular modelling software for visualising complex molecular structures during Genetics and Molecular Biology instruction.	2.75	0.80	HE
	Grand Mean	**2.60**	**0.87**	**HE**

Note: $\bar{X}$ = Mean; SD = Standard Deviation; HE = High Extent; LE = Low Extent. Decision criterion: 2.50.

Data in Table 2 show that the illustrative mean ratings of lecturers on the extent of utilisation of molecular modelling software in Genetics and Molecular Biology instruction ranged from $\bar{X}$ = 2.32 to $\bar{X}$ = 2.78, with standard deviations ranging from SD = 0.80 to SD = 0.96. Items 1, 2, 4, 6 and 7 recorded mean ratings of $\bar{X}$ = 2.78, 2.64, 2.71, 2.59 and 2.75, respectively, indicating a high extent (HE) of utilisation. Conversely, items 3 and 5 recorded mean ratings of $\bar{X}$ = 2.43 and $\bar{X}$ = 2.32, respectively, indicating a low extent (LE) of utilisation. The grand mean ($\bar{X}$ = 2.60) and average standard deviation (SD = 0.87) indicate a high extent of utilisation of molecular modelling software in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria, based on the illustrative figures.

Research Question Three: To what extent are digital simulations utilised in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria?

Table 3: Mean Ratings ($\bar{X}$) and Standard Deviations (SD) of Lecturers on the Extent of Utilisation of Digital Simulations in Genetics and Molecular Biology Instruction in South-East Nigeria

S/N	Item Statements	$\bar{X}$	SD	Decision
1	Utilisation of digital simulations for demonstrating DNA replication processes during instructional delivery.	2.81	0.79	HE
2	Utilisation of digital simulations for illustrating transcription and translation processes in molecular biology instruction.	2.73	0.84	HE
3	Utilisation of digital simulations for demonstrating genetic inheritance patterns and Mendelian principles.	2.68	0.86	HE
4	Utilisation of digital simulations for explaining genetic mutations and their effects on gene expression.	2.46	0.91	LE
5	Utilisation of digital simulations for demonstrating chromosome behaviour during mitosis and meiosis.	2.85	0.77	HE
6	Utilisation of digital simulations for illustrating gene regulation and molecular interactions.	2.39	0.94	LE
7	Utilisation of digital simulations for demonstrating recombinant DNA technology and genetic engineering procedures.	2.58	0.88	HE
	Grand Mean	**2.64**	**0.86**	**HE**

Note: $\bar{X}$ = Mean; SD = Standard Deviation; HE = High Extent; LE = Low Extent; VHE = Very High Extent; VLE = Very Low Extent. Decision criterion = 2.50.

Data in Table 3 show that the illustrative mean ratings of lecturers on the extent of utilisation of digital simulations in Genetics and Molecular Biology instruction ranged from $\bar{X}$ = 2.39 to $\bar{X}$ = 2.85, with standard deviations ranging from SD = 0.77 to SD = 0.94. Items 1, 2, 3, 5 and 7 recorded mean ratings of $\bar{X}$ = 2.81, 2.73, 2.68, 2.85 and 2.58, respectively, indicating a high extent (HE) of utilisation. Conversely, items 4 and 6 recorded mean ratings of $\bar{X}$ = 2.46 and $\bar{X}$ = 2.39, respectively, indicating a low extent (LE) of utilisation. The grand mean ($\bar{X}$ = 2.64) and average standard deviation (SD = 0.86) suggest a high extent of utilisation of digital simulations in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria, based on the illustrative figures.

Research Question Four: To what extent are electronic scientific databases utilised in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria?

Table 4: Mean Ratings ($\bar{X}$) and Standard Deviations (SD) of Lecturers on the Extent of Utilisation of Electronic Scientific Databases in Genetics and Molecular Biology Instruction in South-East Nigeria

S/N	Item Statements	$\bar{X}$	SD	Decision
1	Utilisation of electronic scientific databases for accessing current research publications in Genetics and Molecular Biology instruction.	2.91	0.76	HE
2	Utilisation of electronic scientific databases for retrieving genetic sequence information during instructional delivery.	2.72	0.83	HE
3	Utilisation of electronic scientific databases for accessing protein sequence and structural information during lectures.	2.64	0.86	HE
4	Utilisation of electronic scientific databases for demonstrating nucleotide sequence analysis using genomic repositories.	2.43	0.92	LE
5	Utilisation of electronic scientific databases for accessing gene expression datasets during molecular biology instruction.	2.36	0.95	LE
6	Utilisation of electronic scientific databases for illustrating genetic variations and mutations using genomic information.	2.69	0.84	HE
7	Utilisation of electronic scientific databases for providing students with scientific literature and genomic information for instructional activities.	2.82	0.79	HE
	Grand Mean	**2.65**	**0.85**	**HE**

Note: $\bar{X}$ = Mean; SD = Standard Deviation; HE = High Extent; LE = Low Extent. Criterion mean = 2.50.

Data in Table 4 show that the illustrative mean ratings of lecturers on the extent of utilisation of electronic scientific databases in Genetics and Molecular Biology instruction ranged from $\bar{X}$ = 2.36 to $\bar{X}$ = 2.91, with standard deviations ranging from SD = 0.76 to SD = 0.95. Items 1, 2, 3, 6 and 7 recorded mean ratings of $\bar{X}$ = 2.91, 2.72, 2.64, 2.69 and 2.82, respectively, indicating a high extent of utilisation, while items 4 and 5 recorded mean ratings of $\bar{X}$ = 2.43 and $\bar{X}$ = 2.36, indicating a low extent of utilisation. The grand mean ($\bar{X}$ = 2.65) and average standard deviation (SD = 0.85) indicate a high extent of utilisation of electronic scientific databases in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria, based on the illustrative figures.

Research Question Five: To what extent are interactive digital learning platforms utilised in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria?

Table 5: Mean Ratings ($\bar{X}$) and Standard Deviations (SD) of Lecturers on the Extent of Utilisation of Interactive Digital Learning Platforms in Genetics and Molecular Biology Instruction in South-East Nigeria

S/N	Item Statements	$\bar{X}$	SD	Decision
1	Utilisation of interactive digital learning platforms for delivering Genetics and Molecular Biology lectures through online instructional environments.	3.12	0.74	HE
2	Utilisation of interactive digital learning platforms for sharing instructional materials on genetic and molecular biological concepts.	3.06	0.78	HE
3	Utilisation of interactive digital learning platforms for conducting interactive discussions on genetic inheritance and molecular processes.	2.87	0.82	HE
4	Utilisation of interactive digital learning platforms for administering online quizzes and assessments in Genetics and Molecular Biology courses.	2.94	0.80	HE
5	Utilisation of interactive digital learning platforms for organising collaborative learning activities involving genetic and molecular biological concepts.	2.46	0.91	LE
6	Utilisation of interactive digital learning platforms for providing instructional feedback on Genetics and Molecular Biology learning activities.	2.76	0.85	HE
7	Utilisation of interactive digital learning platforms for facilitating students' participation in virtual discussions and problem-solving activities.	2.39	0.94	LE
	Grand Mean / Average SD	**2.80**	**0.83**	**HE**

Note: $\bar{X}$ = Mean; SD = Standard Deviation; HE = High Extent; LE = Low Extent; VHE = Very High Extent; VLE = Very Low Extent. Criterion mean = 2.50.

Data in Table 5 show that the illustrative mean ratings of lecturers on the extent of utilisation of interactive digital learning platforms in Genetics and Molecular Biology instruction ranged from $\bar{X}$ = 2.39 to $\bar{X}$ = 3.12, with standard deviations ranging from SD = 0.74 to SD = 0.94. Items 1, 2, 3, 4 and 6 recorded mean ratings of $\bar{X}$ = 3.12, 3.06, 2.87, 2.94 and 2.76, respectively, indicating a high extent (HE) of utilisation. Conversely, items 5 and 7 recorded mean ratings of $\bar{X}$ = 2.46 and $\bar{X}$ = 2.39, respectively, indicating a low extent (LE) of utilisation. The grand mean ($\bar{X}$ = 2.80) and average standard deviation (SD = 0.83) indicate a high extent of utilisation of interactive digital learning platforms in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria, based on the illustrative figures.

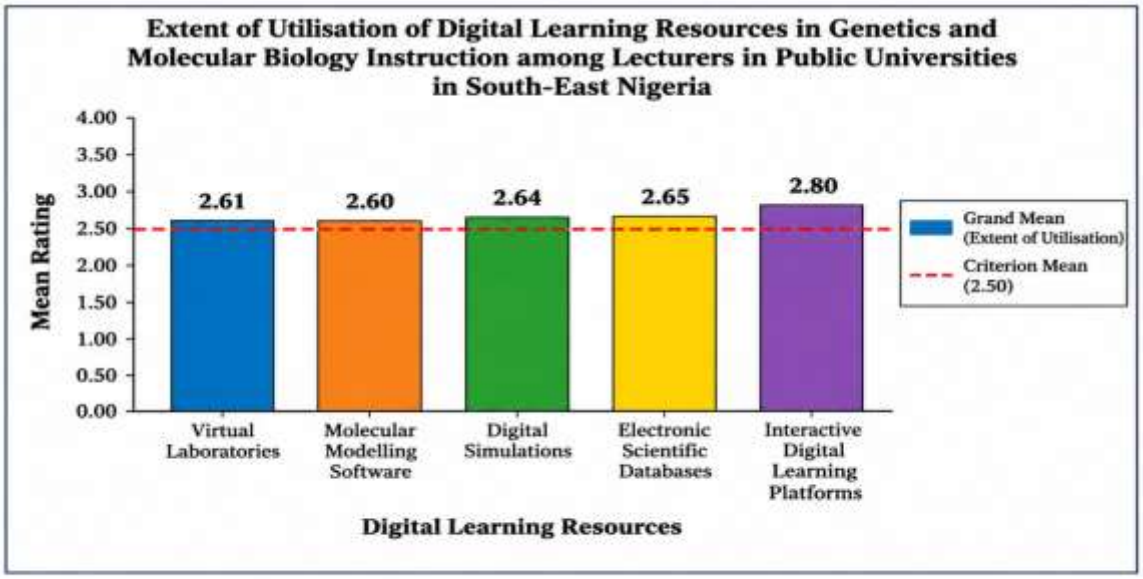


Figure 1: Extent of Utilisation of Digital Learning Resources in Genetics and Molecular Biology Instruction among Lecturers in Public Universities in South-East Nigeria.

Figure 1 presents the extent of utilization of digital learning resources in Genetics and Molecular Biology instruction among lecturers in public universities in South-East Nigeria. The findings revealed that interactive digital learning platforms recorded the highest grand mean of 2.80, followed by electronic scientific databases (2.65), digital simulations (2.64), virtual laboratories (2.61) and molecular modelling software (2.60). All five digital learning resources recorded mean ratings above the criterion mean of 2.50, indicating a high extent of utilisation. The findings further revealed that although interactive digital learning platforms were the most utilised resources, molecular modelling software recorded

the lowest extent of utilisation. This suggested that lecturers in public universities in South-East Nigeria generally utilised digital learning resources in Genetics and Molecular Biology instruction, although differences existed in the extent of utilisation across the five resource categories. The findings highlighted the need for continuous professional development, improved access to specialised digital instructional resources and strengthened curriculum supervision to enhance instructional effectiveness, administrative efficiency and inclusive educational practices.

DISCUSSION

The finding of the study, based on the reported grand mean of 2.61 and average standard deviation of 0.86, indicated that virtual laboratories were utilised to a high extent in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria. The result suggested that virtual laboratories were employed in demonstrating genetic experiments, DNA extraction procedures, simulated genetic activities, gene expression processes and practical molecular biology techniques. However, comparatively lower utilisation was indicated for polymerase chain reaction techniques and gel electrophoresis procedures. This pattern suggested that virtual laboratories were more frequently applied to general instructional demonstrations than to certain specialised molecular laboratory procedures. The finding was consistent with the review conducted by Brinson (2015), which examined empirical research on learning outcomes in virtual, remote and conventional laboratories and reported that non-traditional laboratory environments could support learning outcomes comparable to those achieved through traditional laboratory experiences. The finding was also consistent with Akuegwu, Akeke, Omorobi and Uchendu (2024), who investigated the preparedness of tertiary institutions in Cross River State, Nigeria, for adopting e-learning technology as a mode of instruction. Their study highlighted the importance of institutional preparedness for effective technology-supported instruction. The relatively limited utilisation of specialised virtual laboratory procedures could therefore be understood in the context of differences in technological resources, lecturer competence and institutional support.

The finding of the study indicated that molecular modelling software was utilised to a high extent in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria, as reflected in the reported grand mean of 2.60 and average standard deviation of 0.87. The result suggested that molecular modelling software was applied in illustrating three-dimensional structures of DNA and RNA, demonstrating protein configurations, explaining DNA replication, presenting genetic mutations and visualising complex molecular structures. However, the relatively low mean ratings associated with protein–nucleic acid interactions and molecular docking procedures suggested that more specialised applications of molecular modelling software received comparatively limited instructional attention. The finding was consistent with Graham, Ogbonnaya and Boateng (2024), who investigated lecturers' adoption of information and communication technologies in Ghanaian colleges of education using structural equation modelling. Their investigation provided a relevant basis for understanding the importance of factors influencing lecturers' technology adoption. Similarly, Tonukari and Anyigba (2023) examined e-learning adoption intentions among academic staff in higher education institutions within a developing-country context, drawing attention to the conditions influencing technology acceptance. The finding suggested that the utilisation of molecular modelling software could be strengthened through specialised professional development, improved access to relevant applications and sustained institutional support for advanced digital instruction.

The finding of the study revealed that digital simulations were utilised to a high extent in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria, with a reported grand mean of 2.64 and average standard deviation of 0.86. The result indicated relatively high utilisation of digital simulations for demonstrating DNA replication, transcription and translation, genetic inheritance patterns, chromosome behaviour during mitosis and meiosis, and recombinant DNA technology. Nevertheless, the comparatively low mean ratings recorded for genetic mutations and gene regulation suggested that some complex molecular processes received less attention through simulation-based instruction. The finding was consistent with Bond, Bedenlier, Marín and Händel (2021), who mapped emergency remote teaching in higher education during the first global online semester and documented the extensive adoption of digital technologies for instructional delivery. Their investigation demonstrated the increasing importance of technology-mediated instructional practices in higher education. The finding also related to Brinson (2015), whose review established the educational relevance of virtual and remote science laboratory environments. Furthermore, Eli-Chukwu, Igbokwe, Ifebude, Nmadu, Iguodala, Uma, Onyeneke and Akudo (2023) investigated challenges confronting e-learning in Nigerian higher education institutions during the COVID-19 period and identified constraints affecting effective technology-supported education. These studies provided a basis for understanding why digital simulations could be utilised for relatively familiar instructional processes while more advanced applications remained less frequently employed.

The finding of the study indicated that electronic scientific databases were utilised to a high extent in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria, as reflected in the reported grand mean of 2.65 and average standard deviation of 0.85. The result suggested that lecturers utilised electronic scientific databases for accessing current research publications, retrieving genetic sequences, obtaining protein structural information, illustrating genetic variations and providing relevant scientific literature for instructional activities. However, relatively low utilisation was indicated for nucleotide sequence analysis and gene expression datasets. This suggested that electronic scientific databases were more frequently employed for information retrieval and instructional preparation than for advanced genomic data analysis. The finding was consistent with Ikenwe and Aiyebelehin (2024), who investigated information literacy skills as predictors of the use of digital library resources among academics in selected federal

universities in Nigeria. Their investigation emphasised the relevance of information literacy competencies to the effective use of electronic academic resources. The finding also related to Akuegwu, Akeke, Omorobi and Uchendu (2024), whose investigation addressed institutional preparedness for e-learning technology adoption in Nigerian tertiary institutions. Furthermore, the United Nations Educational, Scientific and Cultural Organization (2023) emphasised the importance of equitable access, appropriate technological integration and institutional capacity in educational technology utilisation. The finding therefore suggested the need to strengthen lecturers' competencies in specialised scientific database applications, particularly genomic sequence analysis and gene expression data interpretation.

The finding of the study revealed that interactive digital learning platforms were utilised to a high extent in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria, with a reported grand mean of 2.80 and average standard deviation of 0.83. The result indicated relatively high utilisation of interactive platforms for online lecture delivery, distribution of instructional materials, academic discussions, online assessments and provision of instructional feedback. However, comparatively low utilisation was recorded for collaborative learning activities and virtual problem-solving participation. This pattern suggested that interactive digital learning platforms were more frequently utilised for instructional communication, content distribution and assessment than for collaborative and participatory learning experiences. The finding was consistent with Bond, Bedenlier, Marín and Händel (2021), whose investigation documented the widespread adoption of digital instructional platforms during emergency remote teaching in higher education. Similarly, Tonukari and Anyigba (2021) examined barriers to e-learning adoption from an entrepreneurial and strategic perspective, providing insight into institutional and organisational considerations associated with digital technology implementation. The finding was also relevant to Eli-Chukwu, Igbokwe, Ifebude, Nmadu, Iguodala, Uma, Onyeneke and Akudo (2023), who examined challenges confronting e-learning in Nigerian higher education institutions. In addition, the United Nations Educational, Scientific and Cultural Organization (2023) emphasised that meaningful educational technology integration should promote accessibility, participation and inclusive learning opportunities. The finding therefore suggested that greater attention should be directed towards the pedagogical application of interactive platforms for collaborative learning, active student engagement and inclusive Genetics and Molecular Biology instruction.

EDUCATIONAL IMPLICATIONS OF THE STUDY

The findings of the study have important implications for curriculum supervision, instructional effectiveness, administrative efficiency and inclusive educational practices in universities. The reported high extent of utilisation of digital learning resources suggests that virtual laboratories, molecular modelling software, digital simulations, electronic scientific databases and interactive learning platforms could enhance the teaching of complex Genetics and Molecular Biology concepts. However, the relatively low utilisation of certain specialised applications highlights the need for continuous lecturer training, improved technological infrastructure and effective curriculum supervision. The findings also underscore the importance of institutional policies that promote equitable access to digital resources, encourage collaborative learning and strengthen administrative support for technology-driven science education.

CONCLUSION

Based on the reported findings, the study concluded that digital learning resources were utilised to a high extent in Genetics and Molecular Biology instruction among university lecturers in South-East Nigeria. Interactive digital learning platforms recorded the highest extent of utilisation, followed by electronic scientific databases, digital simulations, virtual laboratories and molecular modelling software. However, specialised applications involving molecular docking, genomic data analysis, gene regulation and collaborative digital learning recorded comparatively low levels of utilisation. These findings suggest that although digital technologies have become important instructional resources, their application remains uneven across specialised areas of Genetics and Molecular Biology. The study therefore concluded that strengthening lecturers' technological competencies, improving access to specialised digital resources and promoting effective curriculum supervision are important considerations for enhancing instructional quality, administrative efficiency and inclusive educational practices in university science education.

RECOMMENDATIONS

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

1. Nigerian University management should provide adequate virtual laboratory facilities and strengthen lecturers' practical competencies in specialised molecular techniques, particularly polymerase chain reaction and gel electrophoresis.
2. University administrators should organise regular professional development programmes on molecular modelling software, particularly molecular docking, protein–nucleic acid interactions and advanced molecular visualisation techniques.
3. Curriculum supervisors should encourage the integration of digital simulations into specialised instructional activities, particularly genetic mutations, gene regulation and other complex molecular processes.
4. University libraries and ICT units should improve access to electronic scientific databases and provide specialised training on genomic sequence analysis, gene expression datasets and other advanced scientific applications.
5. University lecturers should increase the utilisation of interactive digital learning platforms for collaborative learning, virtual problem-solving activities and inclusive student participation in Genetics and Molecular Biology instruction.

Corresponding author: Dr. Chioma E. Chukwuji - Department of Educational Management and Policy, Faculty of Education, University of Nigeria, Nsukka

Funding: The study received no external financial support from any government agency, institution, organisation or funding body. The research was independently funded by the authors.
Conflicts of Interest: The authors declared that there were no financial, professional or personal conflicts of interest that could have influenced the design, conduct, analysis, interpretation or reporting of the study.
Data Availability Statement: The datasets generated and analysed during the study are available from the corresponding author upon reasonable request, subject to confidentiality and applicable institutional requirements.
Authors' Contributions: The authors contributed to the conceptualisation, research design, instrument development, data collection, data analysis, interpretation of findings and manuscript preparation. All authors reviewed and approved the final manuscript.
Acknowledgements: The authors expressed appreciation to the lecturers in public universities in South-East Nigeria who participated in the study. Appreciation was also extended to the three experts in the Faculty of Education, University of Nigeria, Nsukka, for their contributions to the validation of the research instrument.

REFERENCES

1. Akuegwu, B. A., Akeke, M. N. G., Omorobi, G. O., & Uchendu, C. C. (2024). Adopting e-learning technology as a mode of instruction: How prepared are tertiary institutions in Cross River State, Nigeria? *Journal of Education and e-Learning Research, 11*(3), 490–498. Retrieved from: doi:10.20448/jeelr.v11i3.5860
2. Bond, M., Bedenlier, S., Marín, V. I., & Händel, M. (2021). Emergency remote teaching in higher education: Mapping the first global online semester. *International Journal of Educational Technology in Higher Education, 18*, Article 50. Retrieved from: doi:10.1186/s41239-021-00282-x
3. Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. *Computers & Education, 87*, 218–237. Retrieved from: doi:10.1016/j.compedu.2015.07.003
4. De-Jong, T., Linn, M. C., & Zacharia, Z. C. (2013). Physical and virtual laboratories in science and engineering education. *Science, 340*(6130), 305–308. Retrieved from: doi:10.1126/science.1230579
5. Eli-Chukwu, N. C., Igbokwe, I. C., Ifebude, B., Nmadu, D., Iguodala, W., Uma, U., Onyeneke, R. U., & Akudo, F. U. (2023). Challenges confronting e-learning in higher education institutions in Nigeria amid COVID-19. *Journal of Applied Research in Higher Education, 15*(1), 238–253. Retrieved from: https://eric.ed.gov/?id=EJ1360777
6. Graham, M. A., Ogbonnaya, U. I., & Boateng, E. K. (2024). Analysis of Ghanaian colleges of education lecturers' ICT adoption using structural equation modelling. *International Journal of Learning Technology, 19*(3), 352–379. doi:10.1504/IJLT.2024.142513
7. Hodges, C., Moore, S., Lockee, B., Trust, T., & Bond, A. (2020). The difference between emergency remote teaching and online learning. *EDUCAUSE Review*. Retrieved from: https://er.educause.edu/articles/2020/3/the-difference-between-emergency-remote-teaching-and-online-learning
8. Ikenwe, I. J., & Aiyebelehin, A. J. (2024). Information literacy skills as predictors of the use of digital library resources by academics in selected federal universities in Nigeria. *International Journal of Education and Development Using Information and Communication Technology, 20*(1), 25–38. Retrieved from: https://eric.ed.gov/?id=EJ1425965
9. Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning and Instruction, 60*, 225–236. doi:10.1016/j.learninstruc.2017.12.007
10. Rapanta, C., Botturi, L., Goodyear, P., Guàrdia, L., & Koole, M. (2020). Online university teaching during and after the COVID-19 crisis: Refocusing teacher presence and learning activity. *Postdigital Science and Education, 2,* 923–945. Retrieved from: https://doi.org/10.1007/s42438-020-00155-y
11. Smetana, L. K., & Bell, R. L. (2012). Computer simulations to support science instruction and learning: A critical review of the literature. *International Journal of Science Education, 34*(9), 1337–1370.
12. Tonukari, T., & Anyigba, H. (2021). Reframing barriers to e-learning adoption: An entrepreneurial and strategy perspective. *African Journal of Business Management, 15*(8), 184–197. doi:10.5897/AJBM2021.9246
13. Tonukari, T., & Anyigba, H. (2023). Examining e-learning adoption intention among academic staff in higher education institutions: A developing country context. *Educational Research and Reviews, 18*(12), 399–414. doi:10.5897/ERR2023.4321
14. Turnbull, D., Chugh, R., & Luck, J. (2021). Transitioning to e-learning during the COVID-19 pandemic: How have higher education institutions responded to the challenge? *Education and Information Technologies, 26(*5), 6401–6419. Retrieved from: https://doi.org/10.1007/s10639-021-10633-w
15. United Nations Educational, Scientific and Cultural Organization. (2023). *Global education monitoring report 2023: Technology in education—A tool on whose terms?* Paris, France: Author. Retrieved from: https://www.unesco.org/gem-report/en/2023-technology
16. Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education – Where are the educators? Inte*rnational Journal of Educational Technology in Higher Education, 16,* Article 39. Retrieved from: https://doi.org/10.1186/s41239-019-0171-0