THE ROLE OF TECHNOLOGY ON BIOLOGY EDUCATION IN NIGERIAN SECONDARY SCHOOLS: A REVIEW

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Abstract - Globally, the enormous rise and advancement of information and communication technology (ICT) has improved many facets of life and brought about substantial improvements in the society. The educational sector stands out as a prominently visible domain where ICT is bringing about dynamic changes. In Nigeria, the integration of ICT into biology education at the secondary school level is of paramount importance because of the pivotal role biology plays in nation-building. However, despite its importance, there is a persistent trend of underperformance among senior secondary school students in biology in Nigeria. This is partly due to outdated teaching methods that emphasize memorization only and hinder understanding. There is a need to adopt innovative teaching methods, with a particular emphasis on ICT-based approaches. This research reviews ICT utilization in teaching biology, aiming to identify essential ICT facilities, recognize implementation challenges, and provide recommendations for enhancing ICT-based teaching methods in the Nigerian secondary school system. By implementing these recommendations, Nigerian secondary schools can harness the full potential of ICT in biology education, thereby advancing the nation's educational landscape.

Keywords: ICT, biology education, science, secondary schools, student's performance, teaching methods, Nigeria.

I. INTRODUCTION

The rapid proliferation of information and communication technology (ICT) has ushered in a wide array of more efficient activities across the globe. Undoubtedly, the advent of ICT has instigated profound societal changes, elevated our quality of life, optimized the execution of diverse tasks, and offered solutions to numerous challenges in our day-to-day existence [1], [2], [3], [4], [5]. ICT has revolutionized business practices, facilitated the sharing of knowledge and learning, facilitated the global exchange of information, empowered individuals and communities, reshaped governance, and contributed to substantial economic growth and the establishment of a global information society [6], [7].

Ajayi [8] described Information and Communication Technology as a technological means of collecting, collating, and conveying information using technology.. UNESCO [9] defined as forms of technology that are used to transmit, store, create, share or exchange information. According to Tamiselvan *et al.* [6], it is a field that encompasses any product that is capable of electronically storing, retrieving, manipulating, transmitting, or receiving information in a digital format. It not only focuses on these individual functions but also emphasizes the importance of how these different functions can interact and work in synergy with each other. Prakash & Naik [10] stated that ICT encompasses the integration of communication technologies and computers that collectively empower users to efficiently access,

store, transmit, and manipulate information. Additionally, Shokeen *et al.* [11] characterized it as the application of computer systems and internet connectivity for the management and communication of information.

From the definitions provided above, it is therefore deduced that ICT refers to the dynamic use of technology tools and systems to gather, process, analyse, store, retrieve, manipulate, transmit, and receive information in a digital format. It refers to a wide range of products, software, and networks that enable the seamless exchange, sharing, and creation of information. Individuals and businesses benefit from ICT because it improves communication, enables effective data management, fosters collaboration, and promotes technological innovation.

ICT serves as a catalyst for societal progress, transforming the way we communicate, work, learn, and engage in a rapidly evolving digital world. These technologies include communication mediums such as radio, television, video, DVD, and telephones, including both fixed-line and mobile devices [9]. ICT primarily centers around communication technologies, encompassing the internet, wireless networks, cell phones, and various other mediums of communication [12]. This field plays a crucial role in facilitating effective and efficient communication in today's interconnected world. Gupta *et al.* [13], attributes the adoption of information and communication technology (ICT) in various sectors. These include the significant growth of ICT implementation in education, healthcare, energy, industry, banking, employment, tourism, hospitality, sports, recreation, agriculture, and several others.

Without a doubt, the educational sector stands out as a prominently visible domain where ICT is bringing about dynamic changes, impacting every area of teaching and learning and making its tremendous influence obvious [14], [15]. This transformation is evident in the empowerment of students, educators, and administrators through a wide array of digital tools, interactive platforms, and personalized learning experiences. It is revolutionizing traditional educational paradigms by fostering opportunities like e-learning [16], virtual schools [17], digital libraries [18], e-books [19], and creating inclusive learning environments [19], [20]. Studies by various researchers show that the integration of ICT in schools has predominantly positive impacts on both teachers and students [21], [22], [23], [24] [25]. In numerous surveys, teachers, students, and school administrators have reported substantial improvements in the quality of students' work, as well as in the quality of teaching, learning, and research activities within the school environment, resulting from the incorporation of ICT into the learning environment [26], [27], [28]. Its effective utilization is expected to drive a significant transformation in secondary school education, particularly in the field of Biology [29], leading to rapid growth and enhanced learning experiences for both instructors and students, especially in light of the profound impact of COVID-19 on students, teachers, and educational organizations worldwide. This global crisis has fundamentally changed the perception of the learning process, necessitating adaptations and innovations to meet the evolving needs of education in a digital age [30].

Biology is a distinct field of the natural sciences that deals with the study of plants and animals, contributing to the development of scientific literacy that is necessary for a country's growth and development [31]. The primary objective of biology education is to equip students with a comprehensive understanding of biological concepts, principles, theories, and laws [32]. This knowledge serves as a crucial foundation for preparing the workforce in fields such as medicine, agriculture, and related professions. The contributions of biologists have strategic implications in a wide range of industries, including crime detection, research, healthcare, disease control, population management, agriculture, and education. Furthermore, biology serves as the foundational cornerstone for driving technological advancements. This is exemplified by the fact that nations achieving notable strides in technology owe their success to a dedicated group of science educators, scientists, and technicians who have been educated in the field of biology [33], [34]. This implies, therefore, that the importance of biology cannot be overemphasized.

Biology is a popular subject in Nigerian secondary schools, favoured by senior secondary students and often surpassing enrolment figures of related subjects in Senior School Certificate Examinations, making it a common choice for students aspiring to pursue careers in medicine, engineering, and agriculture [35].

However, despite the popularity of biology and its high enrolment numbers in Senior School Certificate Examinations (SSCE), secondary schools are annually producing high school graduates who are ill-equipped to meet the contemporary demands of science education at the tertiary level [36], [37]. A review of available statistics shows a persistent trend in this underperformance, with students consistently scoring below the 50% threshold in the subject of biology [35]. Despite concerted efforts by government and administrators at various levels to enhance the quality of biology education in the secondary school system, the subpar academic performance among senior secondary school students has shown no signs of abating [38]. This negative trend makes it necessary to consider declaring a state of emergency for biology teaching and learning in Nigerian secondary schools. It is important to recognize that the responsibility for this problem cannot be put solely on the shoulders of the students; a careful analysis of the teaching strategies and methods used is also required.

The authors in [39] noted that the current method of teaching and learning biology used in Nigerian secondary schools is outdated and, as such, hinders the comprehension and retention of biological knowledge and its associated concepts. The current method of teaching and learning biology primarily centers on memorization or 'cramming', which is a practice commonly used by Nigerian secondary school students [40]. Memorization or "cramming" often leads to surface-level learning, where students may be able to recite information for examinations but may find it difficult to apply their knowledge to practical situations or more difficult scientific concepts [41], [42]. The pedagogical approaches used in teaching need to be modernized and varied in order to address this problem [43]. Dickerson [44] asserted that the absence of technology in schools contributes to the prevalence of *"lecture and listen"* instructional scenarios. In such scenarios, teachers predominantly deliver verbal explanations while students listen and take notes. This traditional teaching method is inadequate for preparing students with the essential skills and competencies required to thrive in in the contemporary world [45]. Therefore to improve the quality of education, learning methods need to be modernized and upgraded through the integration of ICT into teaching and learning [46]. This incorporation of technology would facilitate a shift from the traditional model to a more interactive *"show and tell"* approach, enabling a more engaging and effective educational experience.

In the context of teaching biology, ICT techniques have introduced a wide array of technologies that have transformed the traditional biology classroom. Over the past years, various computer technologies and digital tools have been harnessed to enhance students' understanding of the biological sciences in schools [44]. It is important to emphasize that the advocacy for the integration of ICT in biology education in Nigerian secondary schools is not intended to entirely replace the traditional teaching methods or make them ineffective; rather, it aims to complement and enhance them. The combination of both approaches can effectively facilitate the teaching of biology [47]. Bichi & Abdullahi [37] therefore emphasized the need for policymakers involved in curriculum design for biology to include digital innovative teaching strategies that enhance the comprehension of biological concepts. Ratheeswari [12] further supports this notion by suggesting the incorporation of ICT-based teaching and learning methods as an effective strategy.

By integrating ICT-based teaching and learning methods into the biology curriculum, educators can create a dynamic learning environment that deepens the understanding of biological concepts among students. This approach not only enhances the quality of education but also equip students with essential digital literacy skills, preparing them for the demands of the modern world. The students' capacity to understand and remember biological concepts can be improved by embracing ICT-based teaching strategies and interactive learning tools. This strategy would improve students' biology academic performance while also preparing them for careers and further study in the field of biology, advancing scientific literacy and development across the country.

Therefore, the focus of this research is to evaluate the extent of the utilization of ICT in the teaching of biology in Nigerian secondary schools, to identify major ICT facilities that will enable proper learning of biology and its related

concepts, to identify and address challenges in ICT implementation for improved learning, and to offer effective recommendations for enhancing ICT-based teaching methods in biology education in the Nigerian secondary school system.

II. METHOD

This study employed a literature review methodology to comprehensively examine the existing body of knowledge concerning the integration of ICT into Nigerian secondary school biology education. A literature review is a recognized approach for systematically gathering, assessing, and synthesizing existing research and publications on a specific topic [48]. By leveraging on this methodology, the study explored scholarly articles, educational reports, publications, and relevant documents, aiming for a comprehensive understanding of the ICT integration landscape in Nigerian secondary school biology education. Scholarly articles from renowned international journals like JSTOR, SAGE, IEEE, Elsevier, Springer, Hindawi, Nebraska, and other reputable sources were thoroughly examined. Through critical analysis, the study assessed the current state of ICT utilization, its impact on teaching biology in secondary schools in Nigeria, and the associated implementation challenges. With the aim of contributing to a more comprehensive understanding of the subject, this approach facilitated robust examination and synthesis of relevant literature, ultimately informing recommendations for enhancing ICT integration in biology education.

III. RESULTS AND DISCUSSION

A. Assessing the level of ICT Integration in Biology Education in Nigerian Secondary Schools

The ongoing transformation in Africa, as it advances towards the information age, presents a pivotal juncture promising immense progress and development. Nevertheless, a complex challenge known as "*knowledge apartheid*" persists [9]. African students confront the stark reality of having limited access to the extensive information resources enjoyed by their counterparts in more economically prosperous nations. Consequently, many African countries are finding it increasingly challenging to sustain progress, particularly in areas like education [49]. To tackle this issue, it is imperative for African nations to make significant investments in education, particularly in the field of ICT [9]. These investments can help level the playing field, offering African youth equal opportunities to access, acquire, and apply knowledge in today's rapidly evolving digital landscape. By bridging this knowledge divide, African nations can unlock the full potential of their young minds and accelerate their participation in the global information age.

Although Nigeria is making progress in integrating ICT into its education system, the pace of this adoption is very slow [39], and this is clearly affecting the teaching and learning of science subjects, especially biology. Insufficient access to ICT resources in classrooms across public secondary schools hampers effective teaching methods and limits students' exposure to advanced educational tools [50], [51], [52]. To accelerate this process, more effort and collaboration are required from all stakeholders.

In recent years, many advanced industrialized nations have invested significantly in using technology for education. They've provided schools with computers and other related ICT tools, and there is also widespread access to these tools. For instance, the United States had over a million computers in schools as far back as 1986, benefiting more than 15 million students and teachers [53]. Furthermore, in 2011, the United States government allocated a substantial budget of over 900 million dollars to schools, with a significant portion, approximately 60-70%, designated for computer-based education. In Britain and other developed countries, a similar trend of wider computer availability in schools has also been achieved through government funding [54]. This stands in stark contrast to the level of investment made in Nigeria's educational system. According to a report by Vanguard, Nigeria [55], a mere 5.39 percent of the Federal Government's total budget for 2022 was allocated to education, a figure that falls below the UNESCO benchmark (which suggests allocating at least between 15-20%) for educational investment. This lack of adequate

investment in education in Nigeria carries significant repercussions, notably slowing down the progress of education in the country causing it to fall behind developed nations. It is widely acknowledged that increased investment in education, particularly in the fields of science and technology, drives societal advancement. This underinvestment is a key factor contributing to Nigeria's developmental lag compared to more developed countries.

A study by Okebukola [56] substantiates the ongoing challenge in Nigeria. The study revealed that in more than 90% of public schools in the country, computers are notably absent from classroom technology. Regrettably, this situation has not seen marked improvement over the years [57]. Traditional teaching tools like chalkboards, markers, and textbooks continue to dominate classroom activities in most secondary schools throughout Nigeria. However, relying solely on these traditional tools is not enough to adequately prepare students for the demands of the modern digital age. Moreover, this reliance on traditional methods often hinders students' comprehension and application of biological concepts, highlighting the urgent need for integrating ICT into biology education to enhance learning outcomes.

Furthermore, despite the establishment of the Ministry of Communication Technology in Nigeria in 2011 and the subsequent release of a comprehensive 55-page ICT policy document, there are no provisions related to education within this policy [[9]. This omission further highlights the limited attention given to improving education by concerned stakeholders in the country. The lack of adequate investment and attention to education in Nigeria carries significant repercussions, notably slowing down the progress of education in the country and causing it to fall behind developed nations. It is widely acknowledged that increased investment in education, particularly in the fields of science and technology, drives societal advancement. This underinvestment is a key factor contributing to Nigeria's developmental lag compared to more developed countries.

Hence, given the current state of ICT implementation in Nigeria's educational system, there is an evident need for more concerted efforts. All stakeholders must collaborate to expedite progress and close the digital education gap that separates Nigeria from more technologically advanced countries, including some of its African counterparts.

B.   ICT Facilities needed for Biology Education in Nigerian Secondary Schools

In the context of enhancing biology education in Nigerian secondary schools using ICT, it is crucial to identify the fundamental ICT facilities and tools that can empower both teachers and students in the teaching and learning process. These facilities serve as the foundation for the effective integration of ICT in biology education. The following are essential ways in which ICT facilities and tools can be used to effectively teach biology in secondary schools in Nigeria.

1.   Wireless Microphones

One of the reasons for the poor performance in Nigerian secondary schools is the lack of listening comprehension [58]. Classrooms often contend with noise issues due to the large class sizes, making the use of microphones crucial for ensuring students' clear understanding and good listening comprehension [20]. Classroom noise is a common issue in many Nigerian secondary schools due to factors such as overcrowded classrooms, inadequate infrastructure, and often, the sheer enthusiasm of students. In such settings, the teacher's voice can easily become lost, making it challenging for students to grasp the lesson content. Wireless classroom microphones offer a practical solution to this problem. They enable teachers to amplify their voices, ensuring that every student can hear them clearly, regardless of their position in the classroom. This is crucial for effective learning, as children learn best when they can hear and understand their teacher's instructions, explanations, and insights [59].

The research by Baba & Ojakovo [60] highlights the effectiveness of audio materials, particularly microphones, in enhancing listening comprehension. The study shows that utilizing audio equipment is more effective than traditional classroom texts for improving students' listening comprehension skills. Therefore, the incorporation

of audio tools such as microphones can significantly enhance listening comprehension in teaching biology, invariably leading to improved performance among senior secondary school students.

Additionally, students with hearing impairments or those seated at the back of the classroom can participate fully in lessons. The use of these microphones encourages active participation from students. When they can clearly hear their teacher, they are more likely to ask questions, express their thoughts, and engage in classroom discussions. This not only improves their understanding but also fosters a more interactive and engaging learning environment.

2. *The use of computers*

Computers, as emphasized by Senthilkumar *et al.* [20], play a pivotal role in enhancing the efficiency of the teaching and learning process. They significantly improve the teaching and learning of biology, making the process more effective and efficient [53]. These computers come in various forms, such as Personal Computers (PCs) and tablets. These devices are equipped with essential software tools, which can revolutionize the teaching and learning of biology in Nigerian secondary schools. For instance, on a basic level, teachers can use Microsoft Word to create and manage their lesson plans, moving away from traditional pen-and-paper methods. This transition simplifies the lesson planning process and makes it easier to organize and update educational content. Microsoft Excel is another invaluable tool for teachers, allowing them to efficiently record and manage student results and grades. Microsoft PowerPoint is for creating visually stimulating and interactive presentations. These presentations captivate students with multimedia elements and illustrations, enriching the overall learning experience.

Computers therefore opens the gateway to a wealth of teaching resources available on the internet [61]. These resources include e-books, academic journals, and a plethora of educational materials. By using the internet, both teachers and students can access a wide range of supplementary materials to enrich their learning experience and deepen their understanding of biology. It is true that many of the tasks above are not effectively and efficiently done in secondary schools in Nigeria.

3. *Multimedia projectors*

Nowadays, the integration of multimedia projectors into classroom teaching has assumed significant importance, particularly in the context of secondary school biology education [62]. With projectors, students can vividly recall movies, describing the settings and actions with remarkable clarity. It is therefore possible to create a similar environment in the teaching and learning of biology using multimedia projectors. There has been a paradigm shift in students' learning behaviors; they are no longer just audio learners and now prefer audio-visual learning activities. As a result, each topic presented to the students through graphics or videos becomes more specific and realistic. Students can develop better views and have a broad understanding of the course. This therefore enhances students' learning capabilities [63].

In a study conducted by Erwin and Rieppi [64], the effectiveness of multimedia classes was compared to that of traditional classes based on students' performance. The results revealed that students in the multimedia class achieved higher average examination scores compared to their peers in traditional classes. Ngonyani [65] highlighted that using visual aids like projectors improves memory retention, information recall, and student engagement, ultimately leading to enhanced learning outcomes and improved student performance. In another survey by Ojelade and Aregbesola [62], it was concluded that students exposed to multimedia projectors outperformed their counterparts who were not. These underlines the positive impact of multimedia-based approaches on the teaching and learning of biological concepts. This finding can be explained by the fact that multimedia-based teaching methods are student-centered. In this approach, students take an active role, and the teacher serves as a facilitator. This means that students

have more control over their learning, and the teacher is there to guide them and provide extra support when they encounter challenging areas.

4. *Interactive whiteboards*

Interactive Whiteboards (IWBs) serve as valuable tools that significantly enhance the teaching and learning experience in the classroom [66]. IWBs function similarly to traditional chalkboards or whiteboards but offer a multitude of distinct and superior advantages. For instance, once a blackboard or standard white board is covered with notes, diagrams, or illustrations, they must be erased to make room for newer illustrations. Once previous lessons are erased, students will be unable to revisit such content. However, IWBs digitally store previous lessons, allowing students to revisit them as often as needed. This digital storage ensures that valuable educational content is not lost forever.

The content displayed on an IWB is not confined by physical space, granting teachers the flexibility to seamlessly transition between various visual aids, including high-quality images, 3D models, and videos. The key advantage of IWBs lies in their capacity for interactive engagement, which encourages students to actively participate in their learning. With an IWB, students can directly engage with the content by drawing, writing, and manipulating images, fostering a hands-on approach that enhances their comprehension of complex biological concepts, thereby making intricate processes and structures more accessible. Despite the numerous advantages offered by smart boards, it is embarrassing to realize that a significant majority of teachers and students in public secondary schools in Nigeria have never seen an interactive whiteboard [67]. This underlines the pressing need to prioritize and invest in improving the accessibility of ICT tools in Nigeria's public secondary schools.

5. *Interactive educational games*

A game is a structured or partially structured activity, often undertaken for pleasure, but can also serve educational purposes such as teaching, learning and instructing [68]. Educational games serve as an effective alternative to traditional teaching methods, as they serve as a source of motivation for students, kindling their enthusiasm for learning, and crafting an engaging educational experience [69]. The argument for incorporating games stems from the need to adapt to the technological environment where students are already immersed in digital experiences right from childhood. They are usually engaged in activities such as watching cartoons and playing games at home using mobile phones, computers or gaming consoles [70]. However, when these students transition to the classroom, they are often faced with traditional teaching methods that may not fully engage them in the learning process [71]. Therefore, in order to meet the needs of modern learners, education must evolve to incorporate interactive and engaging approaches, such as educational games, that leverage the technology already familiar to students.

In a study [72], the evaluation of educational games impact on students' academic achievement and knowledge retention yielded noteworthy findings. These findings clearly showed a significant enhancement in favor of educational games, emphasizing their effectiveness in engaging students and improving learning outcomes. Furthermore, corroborating the effectiveness of educational games, another study conducted provided compelling evidence that educational games outperformed traditional instructional materials in enhancing students' learning outcomes. The study, conducted by Galeote *et al.*, [73] revealed that educational games not only improved academic achievement but also but also raised students' interest and enthusiasm in the subject area. These findings reinforce the consensus that educational games offer a valuable and superior approach to traditional teaching methods. Utilizing games as an educational tool can enhance the teaching and learning experience, making it more enjoyable for both teachers and students.

In the context of biology education in Nigerian secondary schools, the study by Udeani and Akhigbe [74], observed that both male and female students achieved equitable learning outcomes in a gamified learning environment. The study highlighted gamification as an effective strategy that scaffolds students' learning and promotes the co-construction of knowledge in the biology classroom. This implies that by integrating game elements into biology lessons, students can exhibit increased engagement, motivation, and active participation, leading to a deeper conceptual understanding and retention of biological concepts and providing a more interactive and impactful learning experience for students.

6. *Access to e-Resources*

To enhance the quality of biology education, ensuring easy accessibility to a diverse range of electronic resources for both teachers and students is paramount. [75]. This approach has significant potential to bolster understanding of biology and its related concepts. These e-resources encompass a range of digital tools, including e-books, e-journals, e-mail, e-forums, e-dictionaries, and search engines. Additionally, there is a wealth of academic websites such as Khan Academy, Biology Digest, Zoological Record, Biology Animal Library, Coursera, and educational YouTube channels that offer a rich repertoire of biology lessons, tutorials, and interactive resources [47]. Research indicates that students exposed to lessons through these web resources have expressed positive feedback regarding their educational experiences [76].

As suggested by Isvoran and Tulbure [77], there are also internet resources containing animations and movies illustrating biological concepts and phenomenon. These platforms effectively complement traditional teaching methods by offering supplementary materials that enhance the learning experience of students [47], [78]. These tools possess the potential to ignite students' enthusiasm for learning by making the educational process more enjoyable and by customizing instruction to meet the unique needs of each student.

7. *Digital microscopes*

Digital microscopes, as modern equipment, enable students to observe biological specimens at higher magnification, facilitating a more detailed examination of cells and microscopic organisms [79]. A digital microscope functions similarly to a traditional microscope but offers additional capabilities, enabling the capture, storage, and manipulation of images. Distinct from conventional microscopes, digital microscopes necessitate a computer connection for image viewing. Following image acquisition with a digital microscope, users can save, edit, and perform measurements on the images. Some models are equipped with built-in screens and memory for enhanced convenience. These images can be shared through data projectors or interactive whiteboards and easily distributed for collaborative discussions [80], [81], [82]. Digital microscopes empower students to take part in real experiments, generate meaningful data, and analyze and interpret the data, making them valuable tools in biology education, motivating students and developing the skills of observation and analysis [83].

However, studies [84], [85], [86] conducted in some Nigerian schools suggest scarcity of digital microscopes, with the few available units often being older versions that are not in optimal condition. Additionally, students exposed to these microscopes experience difficulties in using them effectively, resulting from both the lack of an adequate number of microscopes and the poor condition of the existing ones. Therefore, in light of the importance of biology education and the valuable learning opportunities provided by exploring microscopic materials, it becomes crucial to equip in Nigerian secondary schools with digital microscopes. These instruments are crucial for students to explore elements that are invisible to the natural sight but are essential for students to experience directly and study through experiential learning areas such as cellular structures, organs, and microorganisms, which are fundamental aspects of

the biology curriculum [87]. By integrating digital microscopes into school laboratories, students can interact directly and get a deeper grasp of biology.

C. Challenges to the Implementation of ICT in Nigerian Secondary Schools

Implementing ICT in Nigerian secondary schools faces numerous challenges that hinder its effective deployment. These challenges can be attributed to various factors, including infrastructure, funding, training, and policy. Some of the key challenges are presented in the next sub-section [9], [20], [52], [86], [88], [89], [90], [91].

1. *Inadequate ICT policies and strategic planning*

Weak ICT policies and strategic plans at the school and government levels can result in insufficient support and direction for ICT integration efforts. Despite the fact that Nigeria started implementing its ICT policy in April 2001 through the National Information Technology Development Agency (NITDA), there is little to show for it. As it stands, there is no specific policy in place for integrating ICT in Nigerian secondary schools. A well-structured framework is needed to guide the integration of ICT into teaching and learning, as the current traditional methods of teaching are outdated and fail to provide sufficient educational benefits.

2. *Insufficient ICT equipment*

As earlier indicated in the study, the majority of secondary schools in Nigeria are deficient in fundamental ICT equipment. It is essential to note that without the foundational ICT tools in place, the conversation about integrating ICT into the secondary school educational system becomes moot. To bridge this technology gap, the government must take proactive measures to supply ample ICT equipment to schools, whether situated in urban or rural areas. In order for Nigerian students to keep pace with their global peers and gain essential exposure to ICT, this step is paramount.

3. *High Cost of ICT Facilities*

In a developing country like Nigeria grappling with a soaring inflation rate [92], [93], [94] the initial expenses associated with ICT infrastructure and components can prove to be a prohibitive factor, particularly given the limited educational budgetary allocation by the government. Moreover, for the majority of individuals and educational institutions, the option of personal procurement remains unfeasible, as the acquisition of computers is considered a luxury that falls beyond their financial means.

4. Lack of Maintenance Culture

The absence of a proactive maintenance culture among Nigerians presents a substantial barrier to infrastructural development [95], particularly in the integration of ICT into biology education. Ensuring the adequate maintenance of existing infrastructure is essential for achieving educational goals. Neglecting maintenance contributes to infrastructural decay, impeding the effective implementation of ICT tools in biology education and the broader educational landscape of the nation. Thus, addressing this challenge requires not only fostering a culture of regular maintenance but also prioritizing the upkeep of the available ICT infrastructure to enhance teaching and learning experiences in biology classrooms.

5. *Erratic electricity supply*

The effective functioning of ICT is contingent upon a consistent and uninterrupted power supply. Unfortunately, Nigeria is faced with frequent power outages and an unstable electricity infrastructure [96], which has become the prevailing norm. These recurrent interruptions disrupt ICT activities in schools and frustrates the efforts of both teachers and students, making it challenging to conduct lessons and maintain a reliable, continuous digital

learning environment. Immediate action is therefore required to address the ongoing electricity crisis, which has significantly hindered the country's economic growth.

6.   *Inadequate ICT skills*

A substantial number of educators in Nigerian secondary schools possess limited ICT skills [97], while numerous ICT tools remain unfamiliar to both teachers and students. Consequently, there exists a pressing requirement for comprehensive training to enable teachers to adeptly integrate technology into their lessons, given that some of these tools have not been physically encountered by educators and students alike.

7.   *Low Perception of ICT by Teachers and Students*

A lack of awareness and appreciation of the benefits of ICT can result in resistance to its integration by both teachers and students. Some educators and students have grown so accustomed to traditional teaching methods that they may be hesitant to embrace change. The idea of developing lesson plans using a computer can seem foreign and intimidating, while watching instructional videos as a student may seem odd. To overcome this resistance and foster a more technology-friendly environment, there is a critical need for awareness campaigns, teacher and student training, and initiatives to showcase the practical advantages of ICT in education.

8.   *The Moral Deterioration*

The proliferation of internet pornography, cyberbullying, and various antisocial behaviors facilitated by digital tools is a major area of concern. The emergence of these challenges underscores the need for a closer examination of the moral impact of digital technology. For instance, the idea of asking a student to access educational content online may inadvertently expose them to websites promoting inappropriate content, leading to potential moral dilemmas and ethical concerns. In light of these issues, it is crucial to acknowledge the importance of implementing proactive measures to combat and alleviate these challenges. These measures encompass raising awareness, enforcing stringent regulations, and cultivating a digital environment that promotes responsible and ethical online conduct.

IV. CONCLUSION AND RECOMMENDATIONS

This study examined the current state of ICT integration in biology education within Nigerian secondary schools. Through a comprehensive literature review methodology, the existing landscape of ICT utilization in Nigerian secondary school biology education was explored, along with its impact on teaching biology and the associated challenges. Studies show that Nigeria is experiencing a slow pace of adoption of ICT in its educational system, which significantly affects the teaching and learning of biology. However, despite this challenge, the potential benefits of ICT integration in biology education are vast, promising to revolutionize teaching and learning processes, enhance student engagement, and improve learning outcomes. The findings also highlight significant obstacles to effective ICT integration in Nigeria. Therefore, concerted efforts are needed from all stakeholders, such as government agencies, educational institutions, teachers, students, and the wider community, in order to overcome barriers and facilitate the adoption of ICT tools.

Based on the challenges identified in the integration of ICT in the teaching and learning of biology in Nigerian secondary schools, the following recommendations are hereby made:

1. Concerned stakeholders and relevant authorities should develop a comprehensive ICT policy framework at the national and state levels, with a particular focus on integrating ICT into secondary education.
2. There should be a regular review and update of these policies to keep pace with current technological advancements.
3. Priority investment should be given to ICT equipment and infrastructure in secondary schools in order to bridge the digital divide, both in rural and urban areas.

4. Public-private partnerships should be encouraged by the government in order to secure funding for ICT facilities for schools and to ensure their proper maintenance.

5. The Government should introduce subsidy programs or grants to make ICT equipment more accessible to school administrators, teachers and students.

6. School administrators should provide adequate training to staff and students on basic maintenance practices in order to extend the lifespan of ICT resources.

7. There should be collaborative efforts with relevant authorities to address power supply issues, such as investing in alternative energy sources.

8. School administrators should constantly organize a comprehensive ICT training program for teachers and students, covering everything from basic to advanced skills.

9. Government agencies, school administrators, and educators should initiate awareness campaigns to highlight the benefits of ICT in education for both teachers and students.

10. Workshops and seminars should be organized to dispel misconceptions about ICT and build a positive perception of the usage of technology in the classroom.

11. Stringent regulations and monitoring mechanisms should be implemented in order to curb issues like internet pornography and cyberbullying.

12. Students are to be educated about responsible online behavior and digital ethics.

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