Original Article

Remote Laboratory: A Practical Alternative for Actualizing Sustainable Science Education in Post COVID-19 Era - a review

Nathaniel, Francis Okechukwu[1], Okorie, Chinonyerem[2], Chizoba Ude[3], and **Regina I. Enebechi[4]**

[1]Department of Chemistry Education - Institute of Ecumenical Education, Enugu, Nigeria /
Department of Chemistry and Chemical Engineering, - Jianugsu University China
[2]Department of Biology Education - Institute of Ecumenical Education, Enugu, Nigeria
[3]Department of Social Studies Education - Institute of Ecumenical Education, Enugu, Nigeria
[4]Department of Science Education, Faculty of Education,- Nnamdi Azikiwe University, Awka, Nigeria

Abstract
To meet the demands of the United Nations sustainable development objective on education, online learning has gained more attention during the past 10 years. Without the teacher being physically there, various theoretical ideas have been conveyed to students from various parts of the world. Through the use of animated experimental protocols and simulated experiments, remote laboratories, a sort of online learning platform, enable the execution of pricey laboratory practical at little or no cost. In the post-COVID-19 age, this article examines the role of remote laboratories as a useful tool for achieving the sustainable development goal of scientific education. According to reports, online learning has been well received and adapted to, as well as utilized in a variety of industries and organizations. According to reports, virtual laboratories have increased teachers' and students' access to pricey lab equipment, helping to achieve the sustainable development goal. Despite the crucial role that virtual laboratories play in the teaching of practical courses, there has been little to no advancement in the field, particularly in Nigerian science education.

Keywords: Remote lab, sustainable education, practical alternative and actualizing, Covid-19

Introduction

Online learning has always been seen as a viable alternative, especially for adult students looking for higher education alternatives. However, the COVID-19 pandemic's rise has forced educators and students at all educational levels to quickly acclimate to online courses. Early on in the pandemic, the phrase "emergency remote teaching" was used to describe the transition's transient nature (Hodges et al., 2020). Training has periodically been shifted online, then back into a physical classroom, and then back online again due to ensuing increases in the rate of infection. In other cases, training was provided using a hybrid of online and in-person delivery methods known as the HyFlex model, which allows students to attend any way (Beatty, 2019). In either case, educators simply had to figure out a way to make it work, taking into account the possibilities and constraints of the specific learning environment to create useful and effective lesson plans. The use of various distribution techniques has actually had a long history in education because the 1950s with the work of B. F. Skinner (Skinner, 1958), who developed personalized learning programs, teaching machines have offered these programs that provide rapid feedback on the accuracy of the response. Skinner's theories served as the foundation for the first officially acknowledged examples of programmed learning, or "designed" learning experiences.

The use and availability of electronic materials and activities that can now be incorporated into online learning experiences increased in the year 2020. Synchronous web conferencing tools like Zoom and Google Meet have made it possible for professionals from all over the world to participate in online classes (Fulton, 2020). These tools have also made it possible to record presentations so that individual students can watch them whenever it's most convenient for them. Virtual field trips and virtual labs are just two examples of advances made possible by the value of experience, hands-on learning (Penissi, 2020). As a result, it has been successfully demonstrated that online education can serve students of all ages. As a result, the industry can transition from one that primarily serves adult students and higher education to one that increasingly serves students in primary and secondary school. The limitations imposed by the epidemic allowed educators a chance to devise fresh approaches to teaching particular concepts. Despite the fact that reevaluating instructional methodologies was hurried and forced, the experience has given researchers a rare chance to investigate strategies that best enhance learning within the affordances and constraints of the online environment. Particularly, more variation in teaching and learning activities will keep raising concerns about the significance of "seat time" as the foundation for educational credits (Silva, 2015). Multiple distribution method will probably continue to be used with students of all ages (Maloy, 2020; Lockel, 2020). As educators can support pedagogical approaches from a menu of instructional delivery options, a mix that has been supported by earlier generations of online educators, future iterations of online education will no longer be constrained by the traditions of single teaching modalities (Dunlap, 2018). Although more institutions have utilized electronic learning for teaching and learning purposes as a result of growing awareness of its acceptability. Due to a shortage of virtual laboratories in subjects like Chemistry, Biology, and

Physics, online learning of practical science in secondary schools appears to be troublesome in this region of the world. These review articles aim to assess the utility of remote laboratories as a workable substitute for implementing sustainable scientific education in the post-COVID-19 age.

Access to and Flexibility with Regard to Distance Laboratories

Individuals are taught the knowledge, skills, values, and attitudes necessary to forge a powerful nation by the Foundation for National Development Education. Science and technology education are crucial to a country's growth, according to the United Nations Educational, Scientific, and Cultural Organizations (UNESCO), which views education as a fundamental human right. According to Nnaeto (2017), science is a body of knowledge that methodically investigates the nature and behavior of the world through quantifiable observations and experimentation, leading to the formation of theories and the establishment of laws that explain various events. When theoretical knowledge is combined with laboratory experience, science is better comprehended. Laboratory practice is simply understood as the form of learning that takes place in settings where students can practice and experiment with items and materials before directly or in groups observing phenomena and ideas (Haruna et al., 2021). The major objectives of science laboratory teaching and learning processes continue to be improvement of subject matter mastery, development of scientific reasoning skills, with a corresponding increase in understanding the answers to challenging empirical works, as well as the development of practical skills. There were several novel ways used in the education industry before the COVID 19 era (Joshi et al., 2020). When theoretical knowledge is combined with laboratory experience, these cutting-edge changes aimed to provide a better learning environment where students always achieve their learning goals in a more convenient setting. There is no doubt that one of the most difficult transitions that has attracted more attention in the past ten years is the change from the traditional laboratory setting, which is a physical structure where students walk-in to carry out experimental procedures, to an online lab that gives students access to the same equipment and enables them to learn and have real-world practical experience remotely. Although there have been increasing requests for incorporating technology into the classroom setting prior to COVID 19, project-based learning and the learning of problem-solving skills through online instructions were given higher attention.

It has been demonstrated that e-learning is more effective and efficient with fewer connectivity challenges during the teaching-learning process. For an empirical investigation of technology's acceptability by evaluating the level of infusion and acceptance of new information systems, Rowe (2018) reported the creation of numerous theoretical frameworks for including it in learning environments. The Technology adoption Model (TAM), an idealist concept, was used to predict users' adoption of technology in terms of perceived usefulness, ease of use, attitude toward computer use, and behavioral intention to use computers by user-end. (Fayad & Paper, 2015). Although the use of e-learning to teach theoretical concepts expanded beyond the four walls of the classroom and was warmly received by students, there were significant doubts when it came to offering lab experiences for secondary and postsecondary education using e-learning. According to Diwakar et al. (2010), the Government of India adopted a Virtual Laboratory Project that varied web-based digital teaching-learning by personalizing instruction and granting greater degrees of flexibility for obtaining practical scientific abilities. Remotely controlled visual laboratories give undergraduate and graduate students a laboratory platform with animated experimental methodology and simulated versions of real-life investigations. Students in the sciences and engineering. This enables the execution of costly laboratory practical with little to no cost while allowing financially challenged institutions and individuals to have access to laboratory (Diwakar et al., 2016). The Indian government's success continues to be attributed to the increased acceptability and adaptability of virtual labs.

The expense of creating physical experimentation settings and the challenges of maintaining the lab equipment in an advanced student laboratory forced the transition from a physical laboratory to a web-based digital laboratory (Mitra et al., 2005). Information and communication technologies (ICT) have recently weighed in to help the educational sector deal with the difficulties in developing a physical laboratory with novel perspectives of using animations, simulations to create internet-enabled remote laboratories within curriculum (Cassini et al., 2000). According to Maiti and Tripathy (2013), the potential of ICT to enable laboratories to allow users to access genuine scientific data and control different experiments from a distance has sparked the curiosity of student users. Additionally, it has been said that increased ICT use in schools has helped to model a collaborative teaching atmosphere, which has lessened some of the issues associated with a traditional classroom setting (Nair et al., 2012). Electrical engineering and other scientific disciplines have successfully used some virtual labs (Sousa et al., 2010). Students now have the chance to Due to MIT iLabs, which incorporated genuine hardware electrical engineering remote labs and dispersed it across numerous colleges, experiment from the comfort of any internet-accessible browser. (Harward et al., 2008). College of Technology at addition, cameras were installed and connected to an internet facility at Sydney's remote laboratory (Lindsay, 2007). To support engineering education, the Library of Laboratory (LILA) and Virtual Instrument Systems in Reality, a project by the Blekinge Institute of Technology in collaboration with National Instruments in the United States and Axiom EduTech in Sweden, implemented remote panels for electronics labs. Providers of remote collaborative laboratories include European Schoolnet, PROLEARN, and LabShare Sahara. These implementations were made online and available at all times.College of Technology at addition, cameras were installed and connected to an internet facility at Sydney's remote laboratory (Lindsay, 2007). A project by Blekinge Institute of Technology and National Instruments in the United States is called Virtual Instrument Systems. In order to support engineering education, EduTech in Sweden installed remote panels for electronics labs, and Library of Laboratory (LILA) also put up remote laboratories. Providers of remote collaborative laboratories include European Schoolnet, PROLEARN, and LabShare Sahara. These implementations were made online and available at all times.

The complexity and challenges associated with swiftly implementing virtual laboratories across all subjects vary by discipline; despite the fact these remote labs are marketed as a fresh effort to improve educational requirements. Only a small number of studies have been able to design such online platforms (Malani et al., 2012). Virtual laboratories have been successfully applied in the following domains, according to Diwakar et al. (2016). The following fields have successfully used virtual laboratories.

Laboratory for Virtual Neurophysiology

Information sciences are related to ethology, neuroanatomy, cognitive science, neurology, clinical neurophysiology, electrophysiology, biophysical neurophysiology, and other brain sciences through the study of nervous system function, or neurophysiology. The Virtual Neurophysiology

Lab was developed to lower the cost of reagents, minimize the usage of live tissue or animals, and fill the gap left by the lack of lab instructors with in-depth training and experience. It includes remotely controlled experiments, interactive animations, and simulations.

Virtual Neurophysiology Laboratory (Diwakar et al., 2016)

Virtual Biophysics Laboratory

Students can remotely trigger analogs that replicate the behavior of cells and tissues in the biophysics virtual lab. This lab offered a hands-on opportunity to understand biophysical principles like membrane conductivity, electrical activity, and membrane transport as well as the fundamentals of biophysical methods like light microscopy.

Biophysics Virtual Laboratory (Diwakar et al., 2016)

Virtual Lab for Bio-Inspired Robotics

The goal of biophysics virtual laboratories is to strengthen the application of bio-inspired concepts by teaching real-world practical skills in basic electronics. The theory tab, the process section, and the experimental parameters are all parts of any experiment in the lab. The theory lab explained the underlying idea of each experiment, while the method section offered guidance on how to carry out each one and the experimental parameters covered the processes needed. Users were informed of experiment parameter modifications for the virtual experimental lab procedure. There were also tabs for a quiz, a self-evaluation, and an assignment as extra resources. By using the remote labs, users will be able to evaluate their own theoretical and practical knowledge. To estimate user engagement in each experiment, online feedback was employed.

Architecture for a Remote and Virtual Lab

Architecture created the virtual lab for the VLCAP platform and DAQ-based control, allowing remote equipment to be controlled by straightforward push commands sent through an XML configuration file. Controlled access ensured dependability, scalability, and usability for the user-end while providing a modicum of the feel of a typical laboratory. Additionally, it provides a common virtual lab repository with links to experiments, usage data, usage logs, assessment results, and assignments for students that are related.

Even if online laboratories have been incorporated into more advanced courses, the same cannot be true for disciplines like Chemistry, Physics, and Biology, which are among the most fundamental sciences. As the teaching and learning of the practical component of these courses came to an end during the COVID 19 era, the need for virtual laboratories in these fields became increasingly apparent.

Virtual laboratory's Value

Enhance Student Performance: According to research, virtual learning (VL), as opposed to physical laboratory, can enhance student learning performance and attitude (Nair et al., 2014). In comparison to physical laboratories (PL), students that engaged in virtual learning feel they generally understand more concepts, according to Nnaka (2016) and Flowers (2011). According to Malderali et al. (2009), VL increases student learning by a factor of two. Therefore, VL can be utilized to educate students for the real-world experience, abilities, and confidence needed to excel in industry trends and needs.

Eliminates Inadequate Infrastructure

Over the years, Nigerian tertiary institutions had experienced a number of problems that led to poor quality of education and graduates who couldn't fulfil industry requirements. These problems have been attributed to a lack of suitable laboratory workshop/laboratory space, facilities, inadequate inexperienced staff, overcrowded classrooms/workshops/laboratory, out dated curriculum, etc. in science and engineering-related subjects (Oloyede et al., 2017). These elements depend on the institution's owner providing insufficient funding. Reimagine (2018) asserted that in light of the fact that education is not Nigeria's primary industry, it is predicted that government budget allocation for federal and state-owned higher schools will rarely be sufficient. Institutions must seek an affordable and long-lasting remedy to address infrastructure deficiencies in the face of these financial restrictions. As a result, this article proposes that portions if the existing physical infrastructure, such as PL, were changed to a VL. Software-based infrastructure, according to Redel-Macias (2013), is more reliable and cost-effective than traditional infrastructure. By simulating a virtual platform employing 2D or 3D PL components in modeling and game engines, VL could assist alleviate infrastructure concerns.

The platform can be hosted on a cloud server to enable mobility and accessibility from anywhere and anytime, without institutional physical infrastructure or space. VL offers the opportunity of bringing laboratory facilities closer to students. Through VL, students can develop relevant industrial competency and skills required to succeed after graduation. NUC (2016) stated that VL enables institutions to do everything from preparing student better for lab exercise, to taking entire degree programme online

Cost Effective and Sustainable Platform

Cost-effective and sustainable platform: When delivering a very basic practical course to a big class of students, it may take each student many days to personally participate. If equipment breaks down from excessive use, if reagent runs low, or if worn out equipment needs to be replaced, the issue could get worse. Since VL is not subject to the aforementioned restrictions, both fixed and variable expenses are decreased. According to Budai and Kuczmann (2018), VL has a cheaper operating cost because it doesn't age or wear down. Stanford University (2019) claims that it takes only a little work to convert actual experiments into virtual ones, after which you can use them as long as you choose. VL is a developing trend in technical education. Students can use a computer to conduct experiments in a manner that is both time- and money-efficient (Chan, 2009). It provides a cost-saving advantage by enabling Students in the STEM fields to conduct experiments in expensive labs for a small fraction of the price. (NUC, 2019). It is sustainable because students can experiment or practice repeatedly without endangering the platform because of their errors. If VL is web-based, users can access the platform using a computer with an internet connection or a Virtual Reality (VR) headset, which may not require any additional infrastructure. It is not restricted by place, time, or space, making it more or less universally accessible and flexible. The installation and upkeep of VL are also more affordable. It allows educational institutions the possibility to keep pace with contemporary laboratory requirements for industrial and technical progress.

Sharing Expensive Equipment

Using virtual technologies, it is possible to communicate limited, expensive, and specialized resources that have a finite number of users due to time and location constraints. It might be a way to make unused facilities available for best use. A wider range of students can access practical education thanks to VL's ability to free it from PL's physical limitations (Budai and Kuczmann, 2018).

Keep an Adaptable Curriculum

One of the causes of Nigeria's low quality graduates has been cited as outdated curriculum (Orobo, 2018). According to PCAST (2012), the Nigerian tertiary education curriculum needs to be changed in order to accommodate the country's current industrial development. According to Ajimotokan (2011), the most common justification for rejecting curriculum review is because the diverse fields are changing at a rapid pace. However, the author urged Nigeria to accept change, just as other advanced nations had. Orobor (2018) argues that Nigeria should pursue progress by keeping educational programs flexible and regularly adapting them to technological advancements. This study proposes that using software-assisted teaching and learning methods is one practical way this can be accomplished.

Improve Open and Distant Learning (ODL)

In order to increase access to postsecondary education in Nigeria without compromising quality, the National Universities Commission (NUC) is now looking into open and distance learning. ODL has become widely accepted as a substitute for traditional training, according to Flowers (2014). More than ten academic institutions in Nigeria presently hold licenses to offer ODL programs which feature very few courses in engineering and extremely few courses related to **science** (Owoyemi, 2012). In spite of ODL's benefits and promises, learning science in Nigeria is still quite challenging, because print media still dominates the instructional resources. A practical session at media still dominates the instructional resources. Practical sessions at National Open University of Nigeria are held in labs in the study centers or in laboratories their partner universities (Budai et al 2014). Since students are expected to arrive at the venue at the set time, this method hinders the ODL mode promised self-paced learning and freedom. In addition, a number of additional problems that challenge face-to-face learning in traditional universities will emerge. According to this research, incorporating VL within the ODL program will be a superior strategy for providing practical instruction to ODL students. Students will be able to gain the knowledge and practical experience necessary to compete with peers in traditional universities as a result. In VL, teachers are not required; all instructions are included in the experiment description. To provide narratives during virtual experiments, material guides are made (Budai & Kuczmann, 2018). When an institution offers ODL programs, it is handy for its geographically dispersed students to have more access to practical facilities. Since students are expected to arrive at the venue at the set time, this method hinders ODL mode promised self-paced learning and freedom. Several other people are also using VL for their geographically dispersed pupils. Without sacrificing quality, VL can be utilized to support entirely online programs in science and engineering-related subjects.

Eliminate Safety and Risk Concerns

VL eliminate potential risks that might arise during actual experimentation. A high risk coefficient prevents some experiments (radioactive, high-power voltage, concentrated acidic compounds, etc.) from being taught and presented for educational purposes. VL is a platform for experimentation and demonstration that eliminates risk and safety concerns. In addition, before doing actual experiments, VL enables students to explore many concepts and techniques. This lowers the likelihood of equipment damage or manhandling. With VL, mistakes by students are not penalized. It enables students to portray some circumstances that aren't replicable in a lab setting due to technology, according to Redel-Macais (2013).

Boost Student Engagement

In PL, students encounter a number of difficulties, such as restricted access to equipment and reagents, poor technical assistance, time constraints, personal safety concerns, etc. These can lessen students' enthusiasm for practical subjects or courses. Fewer than 40% of students who begin college planning to major in a STEM subject finish a STEM degree, according to Ari-Gur et al. (2013). They confirmed that lack of desire among undergraduates is one reason why they decide to leave engineering areas. The author contends that by involving students in 3D VL investigations, interest and corresponding retention can be increased.

Gaining Access to a Virtual Lab

Laboratories are reopening when the lockdown is reduced or lifted in numerous nations. A laboratory or a researcher would need to adhere to strict protocols, nevertheless. Numerous universities are still using virtual labs for this purpose. Scientists and students at various colleges, including Harvard, Stanford, Berkeley, etc., have been given the chance to digitally tour these crucial facilities without having to worry about access, cost, or, more significantly, safety, thanks to an organization called LABSTER. In addition to this, a number of schools and universities are currently utilizing the virtual lab paradigm. The Middlesex Community College in Massachusetts, the Indian Institute of Technology (IIT), in Mumbai, and other academic institutions are a few of these. In an effort to address the problem of attending for engineering and science students, the Indian Institute of equipment (IIT) Mumbai has recently established a "virtual lab," and numerous institutions and colleges will now have access to this cutting-edge equipment for its science students, Savitribai Phule Pune University (SPPU) in India, will use this virtual lab technology. Other organizations have taken on the responsibility of offering online laboratories for schools, teachers, and students to connect and carry out experimental procedures that reflect a real-life practical, in addition to institutions providing access to virtual labs for their pupils. These are a few of these organizations:

The MERLOT open educational resource provides academic faculties, students, and educational institutions with access to a large collection of virtual laboratories in the physical sciences, mathematics, and engineering to use in place of or in addition to traditional experiments. With hundreds of simulations and interactive features, the Molecular Workbench offers free and open-source virtual science laboratories for teaching and learning across all subject areas, including biology, physics, chemistry, biotechnologies, and nanotechnologies. Different laboratory models and embedded evaluation with real-time reports can be created and customized by teachers. From elementary schools through advanced and tertiary level sciences, the resources are accessible. They are freely accessible and downloadable.

PraxiLabs offers a huge collection of virtual chemistry and physics experiments to educational organizations and students. The experiments can be used to study general, analytical, and organic chemistry and can be carried out without posing significant financial or physical risks. Physics encourages interaction and involvement while also covering topics like electricity, quantum mechanics, thermodynamics, and more. Similarly, Labster gives students access to a lifelike experience that enables them to conduct experiments and hone their abilities in welcoming and risk-free learning environments. Secondary and higher school students can watch films at their convenience for improved assimilation in more than a hundred virtual laboratories.

Conclusion and Recommendations

Virtual laboratories have a number of benefits that have been demonstrated to be helpful for achieving the UN sustainable development target. The lack of virtual laboratories in scientific education in Nigeria leads to subpar progress toward the SDGs. As a result, Nigeria's government and educational administrators should include a virtual science laboratory in the curriculum.

The following suggestions were made.

1. Virtual physics, biology, and chemistry lab programs should all be developed with a high level of adaptability in mind. This will facilitate and enhance students' online and mobile access to such products.
2. Given how beneficial contextually relevant learning materials are to students' understanding of science topics, the government and school administrators should support schools financially by allocating the funds required for their creation and for the training of science instructors in their creation.
3. Students should make an effort to investigate the possibilities provided by the virtual science laboratory software. The program can be used for personalised learning as well as revision.

References

Ari-Gur et al, (2013), Transforming Undergraduate Engineering Education with 3D Virtual Reality Laboratory Paper presented at 2013 ASEE Annual Conference & Exposition, Atlanta, Georgia. https://peer.asee.org/22654

Budai, T. & Kuczmann M, (2018) "Towards a Modern, Integrated Virtual Laboratory System" *Acta Polytechnica Hungarica*, *15*(3), 191-204.

Fayad, R., & Paper, D. (2015). The Technology Acceptance Model E-Commerce Extension: A conceptual frame work. *Procedia Economics and Finance* 26:1000-1006 https://doi.org/10.1016/s2212-5671(15)00922-3

Flowers, (2011). "Investigating the Effectiveness of Virtual Laboratories in an Undergraduate Biology Course." *The Journal of Human Resource and Adult Learning*, *7*(2), 110-116.

Casini. M, D. Prattichizzo, & Vicino, A. (2000). "E-Learning by Remote Laboratories: A New Tool for Control Education. *IEEE transactions on robotics and automation 16*(4), 336-345.

Chan & W. Fok, (2009) "Evaluating learning experiences in virtual laboratory training through student perceptions: a case study in Electrical and Electronic Engineering at the University of Hong Kong." *Engineering Education*, *4*(2),70-75.

Dunlap, J. & Lowenthal, P. (2018). Open Praxis 10, 79–89.

Fulton, C. (2020). Information. *Lear. Science*. 121, 579–585

Haruna, O.I, Basilia, E.D. & Apochi, M.A. (2021). Adoption of science electronic laboratory practical teaching and learning at post covid-19 pandemic era in public senior sencordary schools in gwagwalada. *African Journal of Agriculture and Allied Sciences*. *1* (1), 218-237

Harward V. J et al, (2008) "The iLab shared architecture: A web services infrastructure to build communities of internet accessible laboratories," *Proceedings of IEEE*, *96*(6), 931–950,. http://dx.doi.org/10.1109/JPROC.2008.921607

Hodges, C., Moore, S., Lockee, B., Trust, T. & Bond, M. A. (2020) The difference between emergency remote teaching and online learning. https://go.nature.com/38084Lh

Joshi, A., Vinay, M., & Bhaskar, P. (2020). Impact of coronavirus pandemic on the Indian education sector: perspectives of teachers on online teaching and assessments. Interactive Technology and Smart Education. https://doi.org/10.1108/ITSE-06-2020-0087

Keller, F. S. J. Appl (1989). Behav. Anal. 1, 79–89.

Lindsay, D. Liu, S. Murray, & Lowe, D.(2007) "Remote laboratories in engineering education: Trends in students' perceptions," *Proc. no. MicroLogix* 1200, 1–6,

Lockee, B. J. Appl. Instructional Des. https://go.nature.com/3b0ddoC (2020).

Maiti. A. & Tripathy B. (2013). "Remote laboratories: Design of experiments and their web implementation," *Educational Technology and Society*, *16*(3), 220–233.

Malani. S, G.,Prasanna, N. S., del Alamo, J. A., Hardison, J. L,. Moudgalya, K. & Chopella, V. (2012). "Issues Faced in a Remote Instrumentation Laboratory," in IEEE Fourth International Conference on Technology for Education, 67–74. http://dx.doi.org/10.1109/T4E.2012.21

Maloy, R. W., Trust, T. & Edwards, S. A. (2020). Variety is the spice of remote learning Medium. https://go.nature.com/34Y1NxI

Mitra. S, R. Dangwal, & S. Chatterjee, (2005). Acquisition of computing literacy oshared public computers: Children and the 'hole in the wall, *Australas. Journal of Early Childhood* 13, 1–17.

Nair, R. Krishnan, N. Nizar, R. Radhamani, K. Rajan, A. Yoosef, G. Sujatha, V. Radhamony, K. Achuthan, & S. Diwakar, (2019). Role of ICT-enabled visualization-oriented virtual laboratories in Universities for enhancing biotechnology education – VALUE initiative: Case study and impacts. *Forma Mente*, *7*(1), 209–229

Nsikan. O. J, I. A. Anayo, & E. O. Ekpeyong (2017) Engineering Education and Development in Nigeria Beyond 2020. http://www.globalacademicgroup.com/journals/academic

Nnaka .C. V, (2016). Science Education through Open and Distance Learning at National Open University of Nigeria". IASET: *International Journal of Library and Educational Science*, *2*(1), 1-8.

National Universities Commission (2019). Approved Programmes of Distance Learning centres. http://nuc.edu.ng/distance-learning-centers/

Orobor I. A. Et al., (2018). Cost-Saving and Internally Generated Revenue in Tertiary Educational Institutions: The Role Computing. *International Journal of Education Technology*, *3*(2), 1-7.

Oloyede. A, H., Ajimotokan. A. and Faruk N. (2017). "Embracing the Future of Engineering Education in Nigeria: Teaching and Learning Challenges," *Nigerian Journal of Technology*, *36* (4), 991-1001.

Owoyemi T. E. & Akinsete, A.M. (2012) "Learning science at a distance: National Open University of Nigeria Students' Perception of Practical Work in Learning Science", *proc. EpiSTEME* 5, 364-368.

Onwuka, .K, (2009). Reshaping engineering education curriculum to accommodate the current needs of Nigeria. *Educational Research and Review*, *4*(7), 334-339.

Redel-Macías., S. Pinzi, A. J. Cubero-Atienza, M. P. Dorado, M. P. & Martínez-Jiménez A.

(2013). “Biorefinery Virtual Lab-Integrating E-learning Techniques and Theoretical Learning,” in conf. *International Joint Conference Heidelberg*, 189, 321-330s