

PEDAGOGY OF INFORMATION AND COMMUNICATION
TECHNOLOGY FOR DIGITAL TEACHING AND LEARNING OF
BIOLOGY IN NIGERIA

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ABSTRACT

Teaching and learning in the 21st century, an ICT- driven age is undergoing innovations as a result of the changing demands in the education enterprise. Classrooms have become more inclusive with respect to the diverse needs of gender, cultural and individual differences. Also classrooms have become largely ICT integrated and the norm is towards effective use of ICT materials to enhance teaching and learning. Emphasis, therefore in this computerized age is on life-long learning and the learners are expected to do this using new technologies. These changing dynamics of classrooms situations have also made way for teachers and students to interact using various strategies. accordingly, emphasize is being laid on specific learning theories that are cognitively oriented, addressing, in teaching, new ways of preserving learning behaviors and learning strategies. This motivates teachers and trainers to make the test pedagogical use of ICT in their own teaching and to encourage the development of high quality digital teaching and learning materials. Teleconferencing, webhosting, videoconferencing etc. are example of ways by which ICT has extended human experience in learning.

Keywords: ICT Education, E- learning, Internet, Digital

INTRODUCTION

The advancement of technology has made a significant impact on the evolvement of teaching methods from traditional face-to-face teaching to computer based learning (CBL) or – E-learning systems in all levels of education. Today, a variety of ICT can facilitate not only delivery of instruction, but also learning process itself. Moreover, ICT can promote international collaboration and networking in education and professional development. There's a range of ICT options – from videoconferencing through multimedia delivery to web sites – which can be used to meet the challenges teachers face today. In fact, there has been increasing evidence that ICT may be able to provide more flexible and effective ways for lifelong professional development for today's teachers. In this age of globalization, there is an increasing demand for schools at all levels of education to embrace the opportunities presented by technological development.

Information and Communication Technology (ICT) can be defined as the infrastructure and components that enable modern computing activities. Although there is no single universal definition of ICT, the term is generally accepted to mean all devices, networking components, applications and system that combined people and organizations (i.e businesses, non-profit agencies, government and criminal enterprises to interact in the digital world) (Rouse 2016). According to Technopedia (2017), Information and Communication Technology (ICT) refers to all the technologies used to handle telecommunications, broadcast media, intelligent building management system, audio-visual processing and transmission systems and network-based control and monitoring functions. Although ICT is often considered an extended synonym for Information Technology

(IT), its scope is broader. The entire world has been metamorphosis into a global village by Information and Communication Technology (ICT). Information Blog Archive, (2013) buttressed the fact that the emanation of ICT has caused a lot of development since 1974, the internet which is the global system of interconnected computer network that are linked by a broad array of electronic and practical networking technology is the medium through which all those development were made possible. Information and Communication Technology (ICT) has therefore been observed as the greatest achievement of the 20th and 21st centuries as it has impacted significantly the core of human development and many aspects of human lives such as agriculture, medicine, sciences, and so on. Information and Communication Technology (ICT) has become a major tool for gaining competitive advantage in the corporate world and as such has been integrated into the operations of most high performing organizations in every economy and Nigeria as a nation is not left behind. The demand in Nigerian is expanding exponentially. this increasing in demands for schools can attributed to the advert of the knowledge- driven society (Katz, 2001) that is, a society that requires higher levels of states and qualification for employment. The old practice where a job is for life is no longer tenable as labor market demand knowledge and skills that require regular update. Emphasis, therefore in this computerized age is on life- long learning and the learners are expected to do this using new technologies. To meet the changing world-wide demand for education, electronic learning has been adopted in the developed country to overcome many of the barriers. There is need to appraise the extent to which teachers in Nigerian utilize new technological result in science curriculum delivery. Although ICT has several definitions depending on the nature

of its use, for this purpose, ICT (information and communication technology) is used as an umbrella term that includes any communication device or application, encompassing: radio, television, cellular phones, computer and network hardware and software, satellite systems, as well as the various services and applications associated with them, such as videoconferencing and distance learning. We refer to ICT in the particular context of ICT provision, policy and teacher factors that variously support teaching, learning and a range of activities in education. Information and communication technology refers to information channels such as the World Wide Web, online database, electronic documents, management and accounting systems, intranet, communication channels include e-mail, electronic discussion groups electronic conferences, the use of cell phones, hard wares and soft wares used to generate, prepare, transmit, and store data, such as computers radios, TV, computer programmes / tools (International Institute for sustainable Development, 2007). The term used to cover a whole range of hardware and software. ICTS merges computing with high-speed communications links carrying data, sound and video. Examples include personal computers, telephones, televisions, and various handled devices.

Biology teachers have to distinguish between two groups of ICT applications. In the first groups are generic applications used in all subjects, like word processing, searching for information, communication using e-mails, and multimedia presentations. In this case if a science teacher does not use ICT in classroom damage to the students is limited because they can achieve missing skills with their working on other subjects, or at home (Kuhlemeier and Hemker, 2007), in the second groups are application adapted or developed to be

used in science teaching (McFarlane and Sakellariou, 2002), like imaging system in microscopy (Mc lean, 2000; fiche et al., 2006) virtual laboratory (Jenkins, 2004), and real laboratory exercises with data acquisition systems (Sorgo et al., 2008) the most important difference among this two groups of application is that if a science teacher does not use such applications in teaching students in most cases they will not be able to compensate loss with work in other subject or at home.

The teaching and learning of biology subjects in all levels of education involves helping students to learn science, acquire problem solving skills, develop critical thinking skills, and also helping them to know how and where to obtain needed information, develop the spirits of inquiry and above all prepare them for the process of life-long education (Inomeisa and Osakwe, 2010). Use of ICTS such as computer technology and internet is intended to enables teachers to facilitate learning more effectively and enhance students understanding of concept which are expected to translate into expansion of knowledge and improve examination outcomes. To achieve this, the teachers must deployed new technological resources in the teaching of biological science for maximum benefit. To keep pace with the rapid scientific and technological changes, there is urgent needs to move beyond the passive learning activities that characterize lecture towards more engaged, active and investigative biology lessons.

Computer assisted learning (CAL) packages can be used in diversity of ways the tutorial style may be used by talented or motivated students for exploration of biology contents, remedial help, or for revision. When computers are used for testing or assessments of students they

can provide automated and immediate feedback to a student about their progress and achievement. The use of computer to assess student's performance has been adopted by some schools to reduce cost of marking. The use of computer has the benefits of providing feedback at a speed impossible if marked by staff especially such software used by examination bodies. ICTs offer special opportunities to stimulate growth and increase innovation in every local setting, thereby enabling individuals and institutions to interact more productively with the global economy and the wider world. . . But to realize their potential, technologies must be part of a mix of productive changes and supporting capabilities

ICT and the Teaching and Learning of Secondary School Biology

In Africa, the use of Information and Communication Technology is fast gaining ground in many educational institutions. The case in Nigeria is not different; the use of ICT in the teaching of sciences, especially biology is inherently advantageous and rewarding. Although many secondary schools in Nigeria are still backward in ICT usage and applications. According to Even (2007) in Esharenana and Emperor, (2010), the need for ICT in Nigeria secondary schools cannot be overemphasized because improved secondary school education is essential to the creation of foundation for effective human capital development in any country. Esharenana and Emperor (2010), further recalled that the Federal Government of Nigeria in the National Policy on Education (Federal Republic of Nigeria 2004) recognizes the prominent role of ICT's in the modern world and has integrated ICT into her educational system. Many ICT-driven projects and plans had been launched to make this realizable but due to factors that are not too far from politics, corruption, insurgencies, mismanagement and

lack of political good will, nothing much have been done and realized in this regard.

The Impact of ICT use on Teaching and Learning Biology in Nigeria

Most biology teachers in teacher training institutions have limited knowledge of ways technology can be effectively used in their professional practice. In this age of digitlization, being able to effectively apply technology should be high on the list of what biology teachers at all levels of our education should know and be able to do during biology instructional interaction or transaction. There is no doubt if used appropriately for specific purposes in specific contexts, technology can be an effective tool in supporting teaching and learning of biology. The way Information Communication Technology (ICT) has been used in the education can be divided into two broad categories;

1. ICT for Education
2. ICT in Education

ICT for Education refers to the development of information and communication. Information technologies (ICTs) are information handling tools that are used to produce, store and process, distribute and exchange information. These different tools are now able to work together and combine to form networked world – which reaches into every corner of the globe (UNDP, Evaluation Office, 2001). It is an increasingly powerful tool for participating in global markets, promoting political accountability, improving the delivery of basic services, and enhancing local development opportunities (UNDP, 2006). According to Ogunsola (2005; Torruam and Abur, 2013) ICT “is an electronic based system of information transmission, reception

processing and retrieval, which has drastically changed the way we think, the way we live and the environment in which we live". It can be used to access global knowledge and communication with other people (Ogunsola, 2005; Torruam and Abur, 2003). Students who use ICTs gain deeper understanding of complex topics and concepts and are more likely to recall information and use it to solve problems outside the classroom (Apple computer, 2002; Torruam and Abur, 2013).

The present century is marked by the explosion of scientific knowledge, which has resulted in managing appropriate technological processes and resources. The ICT brings more rich material in the classrooms and libraries for the teachers and students. It has provided opportunity for the learner to use maximum senses to get the information. It has broken the monotony and provided variety in the teaching – learning process (Agashe, L, 1995).

The computers were never developed for improving quality of teaching-learning process. But researchers started using computers for teaching purpose. It gave birth to Computer Assisted Instruction (CAI), Computer Manage Instruction (CMI), Computer Based Instruction (CBI), etc. people started developing CAI for teaching different subjects at school as well as Higher Education level (Haies et'al, 1987). The ICT being latest, it can be used both at school and higher education levels in the following areas;

- Teaching, diagnostic testing, Remedial teaching, evaluation, psychological testing, development of virtual laboratory, online tutoring, development of reasoning and thinking and instructional material development, teachers also enhance their quality by using technology in teaching.

Role of ICT in Biology Teaching

ICT simplifies the part of teaching as visual presentation, we learn 80% of the learning through visual. So the visual presentations of the particular topic could be easily understood by the student teachers. It will be more effective of the student teachers gain knowledge of integrating ICT in their classroom instruction. The use of ICT in higher education level, the information can be delivered very easily and helps the students to understand the particular topic with proper visualization and enjoy the new learning experiences.

ICT has the following advantages:

- ✓ Eliminate time barriers in education
- ✓ Eliminate geographical barriers as learners can log on from any place
- ✓ A synchronous interaction is made possible leading to thoughtful and creative interaction.
- ✓ Enhanced group collaboration made possible via ICT.
- ✓ New educational approaches can be applied.
- ✓ It can provide speedy dissemination of education to target groups
- ✓ It enhances the international, dimension of educational services,
- ✓ It allows for just in time and just enough education for employees in organizations.
- ✓ It can also be used for non-formal education like health campaigns and literacy campaigns (senthilkumar et'al, 2014).

Technology in the Biology Classroom

There are various types of technologies currently used in traditional biology classrooms. They are as follow;

- ✓ **Computer in the classroom.** As a device, computer improves teaching and learning process easily. As an essential tool it integrates ICT in the classroom where the teachers are able to demonstrate a new lesson, illustrate and show new websites.
- ✓ **Class Website.** It is the easiest way to display project work and assignment for students. Once a web page is designed students are provided with classroom works, home works assignments, famous quotations, games and practical lessons on game reserves, zoos or animal life.
- ✓ **Class blogs and Wikipedia.** There are a variety of web 2.0 tools currently being used in the classroom. Wikipedia is a website to allow multiple members to edit a single document. Thus allowing a thoroughly collaborative and carefully edited file.
- ✓ **Wireless classroom microphones.** Classrooms are these days very large and noisy so with the use of microphones while teaching, distractions are prevented and learning take place.
- ✓ **Mobile devices.** Mobile devices like clickers or smart phones can be used to enhance the learning experience of the students in and outside the classroom.
- ✓ **Interactive whiteboards.** This has given opportunity to touch control of computer applications. Thus enhancing the teaching and learning experience in the classroom through computer screen. This not only aids visual learning, it is also interactive and the students can draw, write or manipulate images on the interactive whiteboard.

- ✓ **Digital Video:** LCD projector like equipments equipped our teaching and learning process as proper as possessed DVD players also help us instead of LCD projector.
- ✓ **Online Media:** streamed video websites can be utilized to improve a classroom lesson by using internet.
- ✓ **Online study tools:** These tools make study easier and is also a motivator to studying.
- ✓ **Podcasts:** Podcasting is a relatively new invention that allows anybody to publish files to the internet where individuals can subscribe and receive new files from people by a subscription. Although podcasts are a new phenomenon in classroom, especially in college campuses, studies have shown the differences in effectiveness between live lectures versus podcast are minor in terms of the education of the student.

Criteria for Implementation of ICT in Biology Teaching

Some students believe Biology is a tough subject because of its voluminous concepts. Learning of Biology can therefore be made easier and more interesting by integrating ICT tools in instructional strategies for its teaching. Hence, the teacher education programme at every level should give more emphasis on ICT training for student teachers to apply ICT in their instruction. The curriculum of the teacher education programme should be revised by incorporating the innovative technological equipments for the dissemination of knowledge. Future teachers should be acquainted with these new technologies to make the teaching and learning of process easier and more interesting for

students or learners. ICT directly improves the quality of education and indirectly improves the country's economy (senthilkumar et al, 2014).

Factors influencing the use of ICT in the teaching and learning of Secondary School Biology in Nigeria

Biology is a natural science which occupies an important position in the school curriculum. Biology is central to many science related courses such as medicine, pharmacy, agriculture, Nursing, Biochemistry and so on (Mudashiru, and Adedeji 2010). Ahmed (2008), observed that the performance of students in Biology at secondary school level has been poor and was caused by many factors. Among these factors are: poor quality of science teachers, lack of suitable and adequate science equipments, over-crowded classroom among others. The use of Information and Communication Technology (ICT) in the teaching of Secondary School Biology is advantageous. Biology Teachers in the 21st century are faced with the challenge of teaching the net generation of students which come to class equipped with multimodal learning skills, who are constantly in touch, motivated by and responding to the ever changing world. Biology Teachers therefore, have to change their attitude and "modus operandi" as far as the teaching activities are concerned and adopt modern technology in order to carry out the pedagogic activities with confidence and professionalism (Mathipa and Shirley 2017). The following factors influence the use of ICT in the teaching and learning of Biology in Nigeria:

- (a) The traditional methods of teaching biology do not prepare the learners to be productive which in turn leads to poor performance of biology students in both internal and external examinations. ICT enables learners to operate in the information

society where there is access to rich source of scientific information; which makes the teaching and learning of Biology to be more interesting, enjoyable and a lot more easier. Therefore tackling the problems of poor performance of students in Biology.

- (b) ICT enhances the recall of previous learning experiences, providing new stimuli, activating learner's responses and providing systematic and steady feedback.
- (c) The use of ICT is interactive in nature; most of the ICT platforms encourages interaction between the teacher, the learners and the resource materials. It is effectively used as a learner centered tool instead of traditional pedagogy which is teacher's centered.
- (d) According to Solomon, Augustine and Robert (2017), Information and Communication Technology makes biology teaching and learning more motivating and supportive of productive learning.
- (e) It aids Audio-Visual teaching in the classroom e.g The use of Interactive Marker Board (IMB).
- (f) The use of ICT improves the quality of Biology teaching and learning.
- (g) The use of ICT encourages construction and modeling of biological and scientific knowledge.
- (h) Teachers will opt for ICT because it allows for increased individualization of learning with little or no assistance from the teachers.
- (i) The use of ICT accelerates, enriches, improves and deepens scientific skills as well engaged the students positively and productively.

- (j) Using ICT improves the retentive memory of Biology students as a result of it, Audio-Video qualities.
- (k) Complex and abstract biological processes and procedures like digestion, respiration and genetics can be visualized and demonstrated, this ensures students' comprehension.
- (l) The Biology teacher takes the advantages of ICT to arrest the attention of biology students during the teaching-learning process, encourage students' attendance and increase their concentration.

Types of teaching and learning technological resources

The teaching and learning technological resources can be classified into two:

1. Those that are primary use for communication between people (human to human interaction) otherwise known as communication technologies. This permits communication between teachers and students. Examples include fax, e-mail, radio, teleconferencing, video conferencing and the internet. Those which are primary used by individuals on their own (human to computer interaction). These are used to convey subject contents such as print materials, video tapes, audio tapes, Television, computer based course wares and CD-ROM (compact disk- read only memory). Resources must be matched by resourcefulness – combined with other initiatives by educators and entrepreneurs and in specific terms, the biology instructor to achieve individual and institutional objectives. A study by Romi et al., (2010) found that using computer in biology education resulted in more positive attitude of participants towards biology. Similar finding was reported by Qing (2007) in his study where he found that students had positive perceptions towards

technology that it increased efficiency and make learning easier. It has been proven by Felder and Brent (2004) that student irrespective of their age, tribe or school location are equally hungry for scientific knowledge. It was found that scalable interactive animation with hot keys and rollover help to enhance the learning in effective way, learners experience could be extended when dealing with materials that are in the immediate environment of the learner or, on the other hand, when dealing with materials that could be injurious to the life of the students, for example, a wide animal like a lion cannot be brought into the class live rather a film or video can present its live in the class or a zoo could be networked to the classroom through the internet. Animated illustrations accompany with audio, video and kinetic are much better to cell biology learners than static illustrations (Stith, 2004).

Information technologies ranging from video tapes and laser disks to powerful computing and communication technologies have the potential to recast the relationship between lecturers and their students during science lessons. the challenges facing teachers is being skilled, knowledgeable and having access to the new technological devices, being able to utilize them, as well ability to adopt different approaches to biology curriculum delivery.

Laboratory devices open to teachers for use in biology instructions are.

1. **Use of electronic laboratory (E-laboratory):** E - laboratory is a new computer programme that mimics laboratory experiences. These devices are special media of instructions which have both visual and aural appeal. The utilization of these new technological resources in science instruction makes learning of biology concept clearer to the student and also enables students to engage in critical

thinking, problem solving, and acquisition of new scientific knowledge and skills (Onyegegbu, 2006).

2. **Interactive computers:** the use of interactive computer/ video disc with laser player and color television monitors, projectors, micro computer based instruction and computer- assisted instruction have been very helpful in biology practical lessons. Students using these new technological resources have coincidentally taken less time to complete the science laboratory activities than equivalent instructions delivered by the lecturer (Ulerich, Bybee and Ellis, 1998).
3. **Computer based technologies:** computer is viable medium for the delivery of science instructions. It can be used to download lectures to the instructors thereby by promoting personalized/individualized tutoring. The internet and CD Rom facility available on the computer provide learner opportunity for current information in their courses. A number of computer based technologies have been used for distribution of sample lesson plans on CD ROMs, encouraged the interactive use of the web-based material and use of computer.
4. **Multimedia technologies:** multimedia includes computer –mediated information that is presented concurrently in more than one medium. it consist of some, but not necessarily all, of the following elements: text; still graphic images; motion graphics; animation; hypermedia; photographs; video; and audio, i.e. sounds, music, and narration. Multimedia can support multiple representations of the same pieces of information in a variety of formats. This has several implications for learning. (Ke, 2008).

CONCLUSIONS

Despite the roles of ICT driven instructional aids can play in biology and education at large, Nigerian schools are yet to fully harness its benefits in teaching and learning. Efforts geared towards integration of ICT driven instructional materials into the system, have not had much impact due to several problems ranging from teachers' professional knowledge, poor funding, theft of acquired computers and the effect of corruption.

Technology can be a powerful education multiplier, but must know how to use it. It is not enough to install technology into classrooms – it must be integrated into learning. Nothing can substitute for a good teacher. It is not technology itself that empowers people empowerment comes from skills and knowledge. technology assisted tools can be used to present biological information and concept, to simulate complex content, develop generics skills, to graph and manipulate data and access to student.

RECOMMENDATIONS

Recommendations for prospective and effective use of technology assisted tools in views of the problem hindering use of ICT in Nigerian, the following recommendation are offered for prospective and effective use of technology assisted tools:

- The government of Nigerian should embark on a massive computer literacy training program nation-wide particularly for teachers and learners at all levels. This should be accomplished through in – service training of teachers, seminars and conferences. For student computer education should be a compulsory subject at all levels.

- Curriculum planners should integrate some ICT into specific biology topic/activities.
- All classrooms and auditorium should be connected to the internet in order to enhance web-based instructions. The government should do this by paying internet connection fees to internet service providers (ISP) to provide internet service.
- Video phones, teleconferences and multimedia systems e.g. multimedia computers and multimedia projectors should be provided in adequate quantities by the government for effective usage in schools.
- Teachers in Nigerian should be motivated and encouraged to develop and use multimedia courseware and software relevant to teaching and learning. The government should motivate teachers through provision of adequate funds for courseware development.
- The government of Nigerian should provide digital libraries in every educational institution. The library is the highest reservoir of knowledge and no educational institution can do without it. Ensure that each digital library has a server for storage, retrieval, uploading and downloading of institution.
- The government should employ technologies and technicians to take care of internet facilities and equipment as to carry out routine repairs within education facilities.
- The government should set up standby generators and uninterruptable power supplies (UPS devices) to tackle the problem of epileptic or inconsistent power supply in order to support the use of electronic equipment for teaching and learning.
- National University Commission (NUC) National Commission for College of Education (NCCE) etc should organized accreditation programs more regularly to ensure that this technological device

are available and properly utilized in various universities, college of education and polytechnics.

Philanthropists, nongovernmental organization (NGOs) and other stake holders in education should provide financial aids to schools for the purchase of the technological devices for teaching and learning.

REFERENCES

- Ahmed, M.A. (2008). *Influence of personality factors on Biology lecturers' assessment of difficulty levels of genetics concepts in Nigerian colleges of education*. Unpublished PhD thesis, University of Ilorin, Ilorin.
- Agashe, L. (1995). Role of ICT in primary education to all worldwide journal multi-disciplinary research and development.
- Apple Computer (2002). The impact of Technology on Students' Achievement. Available at: http://www.apple.com/education/reseach/index_2.html. Accessed on 10/7/2012, July, 2017.
- Esharenana, E.A & Emperor, K. (2010). *Application in Nigerian Secondary Schools: Library philosophy and practice*. Retrieved on 30th July, 2017 at <http://www.webpages.uitaho.edu/~mbohn/adomi-kpan-gban.ltm>.
- Felder, R.M and Brent, R (2004). *Navigating the bumpy road to students-centered Instruction*, Retrieved on 19th may 2009 from <http://www.ncsu.edu/felder-public/paper/resi.html>.

- Fiche, M., Bonvin, R., Bosman, F (2006). Microscopes and computers in small group Pathology learning. *Medical Education*, 40(11), 1138-139.
- Fredriksson, U., Jedeskog, G., Plomp, T (2008) Innovative use of ICT in schools based On the findings in ELFE project. *Educations and Information Technologies*, 13(2), Information Blog Archive (2013). *ICT: different uses*. Retrieved on 30 July 2017 from <http://www.786differentusesofict.blogspot.com.ng>.
- Ifeakor, A.C.. (2008). Availability and Usage of Information Communication Technology Facilities by Science Teachers in Anambra State. *Journal of Women in College of Education*, 11(2), 27-29.
- Inomesia,E.A. and Osakwe, E.O. (2010). Principles and Practice of Teaching for Tertiary Students. *Educational Review*, 57 (4), 405-413
- Jenkins, R. (2004). Virtual Unknown™ Microbiology. *Journal of Biological Education*, 38(4), 197-197.
- Katz,R (2001). Campus Champs Tackle heavies. *Times Higher Education Supplement*, May 18.
- Kuhlemeier, H., Hemker, B. (2007). The impact of computer use at home on students Internet skills. *Computers and Education*, 49(2) 460-480.
- Mathipa, E.R & Shirley, M. Teacher Factor influencing the use of ICT in teaching and learning in South African urban schools. *Mediterranean Journal of social sciences*, Vol 5, No. 23 2014. Retrieved on 30 July 2017 from <http://www.mcser.org/journal/index/php/myss/article/viewfile/4647/4510>.

- Mudashiru, O. & Adedeji, O. (2010). Effect of Computer Assisted Instruction (CAI) on Secondary School Students' performance in Biology. *Turkish online Journal of Educational Technology vol. 9, Issue 1*, Retrieved on 30/7/17 from <http://www.files.eric.ed.gov/fulltext/EJ875764.pdf>.
- McFarlane, A., Sakellariou, S. (2002). The Role of ICT in Science Education. *Cambridge Journal of education*, 32(2), 219-232.
- McLean, M. (2002). Introducing computer aided instruction into a traditional histology Course: student evaluation of the educational value. *Journal of audiovisual Media in Medicine*, 23(4), 153-160.
- Ogunsola, L.A. (2005). Information Communication Technologies and the Effects of Globalization: Twenty-First Century "Digital Slavery" for Developing Countries myth or Reality? *Electronic Journal of Academic at*: <http://www.ceoforum.org/downloads/report4.pdf>.
- O'byrne, P.J., Patry, A., Carnegie, J.A. (2008). The development of interactive online Learning tools for the study of anatomy. *Medical Teacher*, 30(8), 260-271.
- Okebukola, P.A.O (2003). *virtual institute for higher education pedagogy*: National University Commission (NUC). Abuja, Nigeria.
- Okoli, J.N; Osuafor, A.M. (2008). Availability, Accessibility and Extent of Use of New Technologies for STM Curriculum Delivery. *49th annual conference proceedings of STAN*, 200-206.
- Onyegegbe, N. (2006). Using New Technologies in Creating Excitement in Biology Laboratory Activities. *47th annual proceedings of STAN*, 134-145.
- Pratt, M.K. (2016). *Information and Communication Technology (ICT), Tech-target Network*. Retrieved on 1st August 2017 from

<http://www.searchCIO.techtarget.com/definition/ICT-information-and-communication-technology-or-technologies>

- Qing, L. (2007). Students and Teacher Views about Technology. Tale of Two Cities. *Journal Of Research on Technology and Education*, 39(4):377-397.
- Ramasundaram, V., Grunwald, S., Mangoet, A., Camerford, N.B., Bliss, C.M. (2005). Development of an environmental virtual field laboratory. *Computer and Education*, 45, 21-34.
- Romi, S., Hanseson, G., Hanseson, A. (2010). E- Learning: A Comparison between Expected and Observed Attitudes of Normative and Drop-Out Adolescents. *Education Media International*.
- Senthilkmar, R. Sivapragasam, C. and Senthamaraikeaman, B. (2014). Role of ICT in Teaching Biology. *International Journal of Research (IJR)* vol. 1, Issue- 9, October, 2014. Pp. 781,785.
- Solomon, I., Augustine, O.O, and Robert, N. Ukpai (2015). *Teachers' factors influencing classroom use of ICT in Nigeria and other sub Saharan African countries*. Retrieved on 30 July, 2017 from <http://www.globa/academicsgropu.com/journals/assertiveness....net>.
- Sorgo, A., Hajdinjak, Z., Briski, D. (2008). The journey of a sandwich: computer based laboratory experiments about the human digestive system in high school biology teaching. *Advances in physiology education*, 32(1), 92-99.
- Torruam, J.T. and Abur, C.C. (2013) the impact of ICT – Driven Instruction Aids in Nigerian Secondary Schools. *International Journal of Basics and Applied Sciences*, in Akademika publications.

Technopedia, (2017). *Information and Communication Technology (ICT)*. Retrieved on 1st

August, 2017 from
<http://www.technopedia.com/definition/24152/information-and-communications-technology-ict>.

UNDP (2006). Information Communication Technologies and Development. Available at: <http://usdnhq.undp.org/it4dev/> accessed 10th July 2012, July, 2017).

UNDP. Evaluation Office (2001). Information Communication Technology for Development. No. 5, pp 1-31.

Ulerich, S.L., R & Ellis, J. (1998). Research on Computers in Schools: from Plato to Logo and beyond. *A paper presented at the annual meeting of the national association for Research in Science Teaching*.

Williams, B. K. and Sawyer, S. C. (2005). Using Information Technology: A Practical Introduction to Computer Communications. Boston: McGraw Hill.

Yusuf, M.O. (2005). Information and Communication Technology and Education Analyzing the Nigerian National Policy for Information Technology. *International Education Journal*, 2005, vol., 6(3), pp 316-311.

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