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Application of ICTs and Educational Software in Teaching Physics: Advantages, Challenges and Proposed Solutions

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ABSTRACT

Information and Communication Technologies (ICTs) and educational software have been integrated into Physics education due to its ability to simplify abstract content, create interest and improve learning outcomes. However, despite the impact of ICTs and educational software, African countries particularly Nigeria has not successfully integrated these technologies into Physics education. Therefore, this paper reviewed the possible ICTs platforms that could be used in studying Physics and advantages of using educational software and integrating ICTs into Physics curriculum. Next, challenges hindering the integration of ICTs into Physics classroom such as infrastructure, funding, professional development, Internet and power supply are discussed. Recommendations are further discussed and possible solutions for these challenges faced by the Physics teachers.

Keywords: Physics, ICTs, Educational software, Physics education, Teaching Physics.

1.0 INTRODUCTION

Science, particularly Physics, is one of the knowledge fields underlying the physical universe and applies continuously to people's ordinary lives. It can be as simple as converting electrical energy to heat, chemical or mechanical energy. Physics can tell us more about everything. Whether you like to know why the world moves, or want to understand the laws of the universe and what makes everything tick – from planets and solar systems to black holes – Physics can explain why things occur the way they do and show us the interaction between phenomena we would not have otherwise seen (Schwartz, Stapp & Beauregard, 2005). Nevertheless, teaching Physics includes more than writing formulas on a chalkboard. It involves developing a learning environment in which students can explore and understand how the matter and energy operate and relate complex science principles to their everyday lives (Ramalingam, Jones, Reba, & Young, 2008). It includes building trust in the ability of student to overcome difficult issues and inspiring them to create a better future for themselves and others. However, despite the benefits of teaching and learning Physics, majority of the students in Africa believed that it is difficult to comprehend some topics as teaching and learning still uses the conventional method (Oakes, Lipton, Anderson & Stillman, 2015). Guido (2018) classified Physics as a difficult subject, not popular, avoided by students and with poor performances in other African countries like Kenya, Niger, Mali, Togo and Chadi.

Previous studies revealed that students had poor performance in Physics subjects/courses (Agbele, Oyelade, &

Oluwatuyi, 2020; Stephen, 2016). Poorly resourced teaching and learning environment, poor mathematical ability and poor teaching method had hindered students' achievement in science subjects particularly Physics (Ugwuanyi & Okeke 2020). Moreover, traditional strategies like demonstration, student centred learning, problem-based learning and project-based learning while having its benefits have not been found to be effective in improving knowledge acquisitions nor developing interest. In tandem with that, research has indicated that integration of Information and Communication Technology (ICT) in Physics curriculum has the capability of simplifying the abstract content as well as creating interest in learners and consequently improving the quality of education (Ndihokubwayo, Uwamahoro, & Ndayambaje, 2020).

ICT is an acronym of Information and Communication Technology. It is a broader term for Information Technology (IT), which refers to all communication technologies, including the wireless network, Internet network, computer hardware and software, middleware, mobile phones, social networking, video conferencing and any other communication mediums that enabling users to store, restore, access, retrieve, transmit and manipulate information in a digital form (Heeks, 2017). ICT is vital instrument for enhancing teaching and learning across the schools. It offers a wide range tools that leads to the change of traditional teaching process (teacher-centred learning) to an inciting and interactive educational process (student-centred learning) (Muianga, Klomsri, Tedre, & Mutimucuio, 2018). Considering the role of ICT in teaching and learning, a question has been asked "Can ICT applied in Physics education help us achieve the desired goals and objectives?" Scholars agreed that if the ICT is well managed and carefully integrated in Physics education, it assists both teachers and students to easily access educational resources and subsequently improve learning outcomes (Kushwaha & Singhal, 2017). ICT is also effective in improving academic qualities by advancing higher order thinking skills, problem-solving skills and improving communication skills (Ali, 2012).

Clearly it has been confirmed that ICT can assist to make Physics education less difficult, more applicable, more connected to the real life and more authentic and can increase the opportunities for own investigations by the teachers and students (Ellermeijer & Tran, 2019). For example, Nggadas and Ariswan (2019) conducted a quasi-experimental study to investigate the differences in the mastery of physics concepts between students are learning by laboratory experiments based-teaching and ICT based-teaching. The results showed that students that learned by ICT based-teaching had better understanding and higher achievement compared to the students who learned by laboratory experiments based-teaching. Dasilva et al (2019) reported that students taught with Android-based interactive physics mobile learning media applications and learning devices performed better and improved higher-order thinking skills (84.80%) compared to the students who taught with traditional teaching method (55.50%).

However, findings of the researches showed that students face difficulties in learning Physics especially practical aspects. An ICT-based method – Physics simulation was compared with demonstration method. The results showed no statistically significant difference between the simulation and demonstration groups in term of their achievements and skills (Wood & Blevins, 2019). Information and communication technologies (ICTs) have been integrated into Physics curriculum in both developing and developed countries. Though, there are few studies assessing the benefits, of using educational software in teaching Physics and possible challenges that teachers might face. Therefore, we discuss the benefits of ICT integration followed by challenges militating against the integration of ICT into Physics education and provide possible solutions for the successful integration of ICT into Physics education.

2.0 Advantages of ICTs integration into Physics classroom

In Physics education, ICTs have immensely contributed and facilitated in understanding the abstract concepts, laws, increased students' performance and encourage successful learning through engaging interactions (Nggadas & Ariswan, 2019). ICT is sometime classified as teaching tools which is fundamental in analyzing and visualizing information, perform experiments and communicate results. There are several studies that revealed the use of educational software and other ICT tools in teaching particularly Physics which indeed enhances students' understanding of scientific facts and ideas; providing students with access to richer sources of data and information; helping students to become autonomous learners; and increasing students' motivation (Briones, 2018; (Ellermeijer & Tran, 2019; Nchunga, & Kira, 2016). Other reasons of integrating educational software and ICT tools in Physics curriculum involve preparing the contemporary students for the industrial work where technologies, such as computers hardware and software, the Internet and other related ICT tools are becoming unavoidable (Okolije, 2016). The following educational software and ICT tools have been found to be beneficial in teaching Physics.

2.1 Educational Software

Education software refers to computer software with the primary aim of self coaching, teaching or self-learning. It is usually developed to simplify difficult concepts, make teaching and learning attractive and motivated. Educational software integrates multimedia content (such as sound, pictures and graphics) and provides users a high interactivity level. Previous studies reported that use of educational software in classrooms and laboratories provides much more effective and efficient environments in teaching and learning Physics. (Moraru, Stoica, & Popescu, 2011). Therefore, the following Physics educational software have been discussed in this study.

I. Oscillations Educational Software is designed for students studying Physics - mechanics with the intent to present an analogous mathematical model. The software has a broader view on oscillations that is extended to optical and heat phenomena. It helps the students with more information on harmonic oscillatory motion, including phasor diagrams, energy, the superposition of perpendicular oscillation, oscillatory motion, chosen from all the fields of classical Physics, optics, electricity, mechanics, and thermodynamics. The effectiveness of this software has been reported in by Moraru et al., (2011).

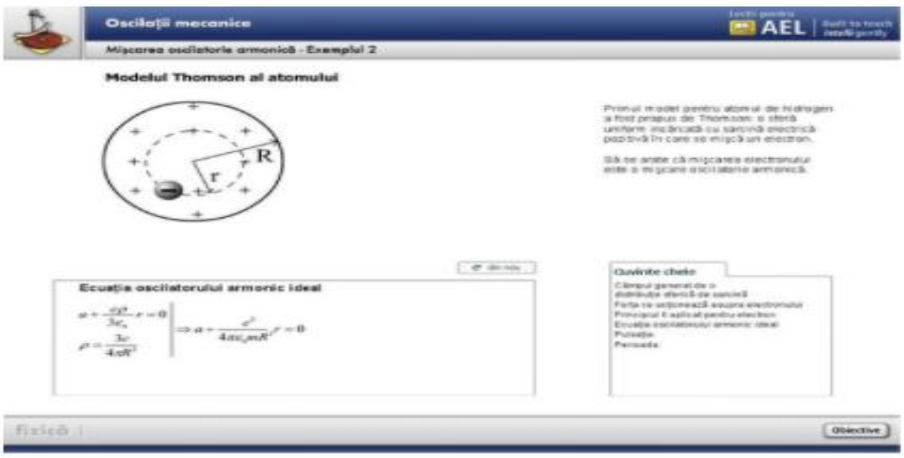

Figure 2.1: Screenshot of Oscillations Educational Software

II. Science of Music Educational Software. The software is used to explain the application of Physics laws in the world of music. It is served as an auxiliary material for students to accelerate class preparation. The application of this software has been recognized as a tool for helping students to comprehend the mathematical laws and practical application of Physics in music.

Figure 2.2: Screenshot of Science of Music Educational Software

III. Fluid Mechanics Educational Software. Fluid Mechanics Educational Software is educational software that was designed from different laws such Pascal's Law, Archimedes's Law, Poiseuille's Law and Bernoulli's Law. The software is useful for those who study biology and/or Physics. It is believed that this application could easily help students to understand the circulation system of human body. Among the objectives of this software are to explain mathematical regularities behind the dynamics of flowing phenomena; attain interdisciplinary transfers in the study of fluids and biology; build a proper use of formal languages (mathematics, Physics and biology); and create connections between various specific physical quantities, mathematical expressions and theoretical biological notions (Stoica, Moraru, & Miron, 2010).

Figure 2.3: Screenshot of Fluid Mechanics Educational Software

Figure 2.4: Screenshot of Algodoo Educational Software

IV. Algodoo Educational Software. In 2008, the first version of Algodoo was designed using the idea of constructionist learning approach in mind, permitting the teachers and students to construct mathematical and scientific knowledge by creating interactive simulations based on Newtonian mechanics and geometrical optics (Gregorcic & Bodin, 2017).

This software was developed because of new development in technology in terms of faster computers and better numerical solving methods, which have made it possible to build high-performance computational Physics engines. Algodoo can be used by the teachers and students to design and run "quick and dirty" simulations in order to start building and understanding of concrete problems. They can make use of various representational possibilities. Algodoo allows the users to display force or velocity vector arrows or a plot of energy. In addition, both vector arrows and plots can be drawn in real time while the simulation is running but can also be paused to allow a stepwise analysis.

***V. Geogebra Educational Software*.** GeoGebra is open source educational software under the GNU General Public License and freely available at www.geogebra.org. The software was design to help students of mathematics and Physics. The GeoGebra educational software is a valuable teaching resource, which can be used to create interactive, dynamic models, useful in the study of physical phenomena. The versatility of the software is high, and the models can be created in a variety of ways, even by students, under the guidance of a teacher.

Figure 2.5: Screenshot of Geogebra Educational Software

Research reported that educational software GeoGebra provides an important intuitive support in the study of oscillatory motion and also initiates students in the use of instruments and methods specific for knowledge and scientific research (Marciuc, Miron, & Barna, 2016).

2.2 Computer Simulation

Computer simulations are applications of special interest in teaching Physics because they can support powerful modelling environments through active participation of students. Computer simulations provide a broad range of possibilities for ideas and processes to model. It offers a connection between the previous experience of students and the learning of new physical concepts, helping students with an active reformulation of their misconceptions to improve scientific understanding. For example, teaching of trajectory motion in school Physics labs is difficult since it demands from students' adequate experimental skills, as well as skills on using stroboscopes. The simulation through interactive is an alternate methodology that provides distinct teaching and pedagogical advantages. The stroboscopic representation of a kinematical phenomenon and the simultaneous display of the position and velocity offer an open environment where students can experiment, research the physical rules, make assumptions or predictions and draw conclusions. To understand the related laws and principles of motion, they can replicate their experiments as many times as they need. Students can easily adjust either the sphere's mass or the constant of gravity and observe the effects on the computer screen immediately. They are primarily open learning environments that offer students the chance to:

i. investigate phenomena that are difficult to encounter in a classroom or laboratory environment due to complexity, technicality, safety, cost and time
ii. use a range of representations (images, animation, graphs, vectors, and numerical data displays) that are helpful in exploring and understanding the underlying concepts, relationships, and processes
iii. isolate and control parameters and thus allow them to understand the interactions between physical concepts, variables, and phenomena
iv. build their knowledge of phenomena and physical laws through a hypothesis-making method and testing of ideas.

Fundamentally, using computer simulation techniques, a student of Physics can analyze, how far succeeded in approaching the actual result while doing an experiment in laboratory (Jimoyiannis & Komis, 2001).

2.3 Multimedia

The term “multimedia” is the field concerned with the computer-controlled integration of text, graphics, drawings, still and moving images (video), animation, audio, and any other media where every type of information can be represented, stored, transmitted and processed digitally (Fiolhais & Trindade, 1998; Meixner, 2017). In other words, it is a media that uses multiple forms of information content and information processing. Research showed that multimedia has positive implication especially in the field of education (Fidan & Tuncel, 2019). Teachers use the media to visualize and simply teaching and learning in the class. Furthermore, interactivity is heightened by the possibility of easy feedback; it is flexible and digital; therefore, it can easily be changed to fit different situations and audiences (Xie, 2018).

The integration of computer interactive multimedia in effective learning helps students to improve their understanding in various concepts of Physics (Kohnle, et al., 2012; Dega, et al., 2013). Interactive multimedia can visualize, simplify and helps students to understand abstract concepts on optics, kinematics, heat transfer, quantum mechanics and thermodynamic. This is stated by Liu (2006) which states that abstract concepts such as the motions laws and gas laws are more easily understood by using multimedia. Doyan and Sukmantara (2014) reported that learning with an effective interactive multimedia enhances the mastery of concepts such as work, energy, and power. Based on the literature review, it is convinced that the use of interactive multimedia using simulations, movies, diagrams, graphics, animations, and sounds plays a vital role to help visualize and simplify abstract concepts that students can not comprehend (Hakim, Liliasari, Setiawan, & Saptawati, 2017). In addition, the power of interactive multimedia is to provide opportunities to study the learning material at any time, respond quickly, develop creative thinking, motivate and develop their interest and encourage curiosity to conduct investigations in Physics.

2.4 Virtual laboratories

Virtual laboratory is an interactive environment without real laboratory tools meant for creating and conducting simulated experiments (Sypsas & Kalles, 2018). A virtual laboratory is one where the student interacts with an experiment or activity which is intrinsically remote from the student or which has no immediate physical reality. It provides students with tools and materials set on computer in order to perform experiments saved on CDs or on web site (Babateen, 2011). Nedic, Machotkd, & Najhlsk (2003) explained other benefits of virtual laboratories which include protecting students from the dangers they face during while conducting some dangerous laboratory experiments. It eliminates the need to deal with toxic or radioactive chemicals and other hazards such as electrical connections; ability to display very accurate phenomena and results that may not be measurable using simple laboratory tools and that require complex and expensive equipment; help students and teachers study and prepare laboratory experiments at any time and place; the student is able to conduct the same experiment several times according his/her ability to absorb the information. This is generally difficult to provide in a real laboratory in the case of limited material and the lack of equipment in proportion to the numbers of students; and the student is given the opportunity to control the inputs of the experiment, change the different transactions, and observe the changes in the results without the existence of a supervisor and without being exposed to any risks. For instance, several studies have been carried out on the effects of virtual laboratory on students' achievement. Falode and Onasanya (2015) argued that virtual laboratory package Hooke's law, simple pendulum and momentum experiment in secondary school Physics curriculum. Similarly, Gambari, et al. (2012) in another study found that students taught Physics practical using virtual laboratory strategy performed better than those taught using conventional laboratory method. Tuysuz (2010) conducted an experimental study on the effect of using virtual laboratory method in Physics practical class and reported that students' skills, understanding and achievement had significantly improved.

3.0 Challenges to ICT integration in Teacher Education from Literature Perspective

The challenges that slow the successful integration of ICT to teaching and learning arena are many and dimensional in nature. We discuss the challenges observed especially in African continent as below:

3.1 Availability of Infrastructure

Experts and researchers in the field of teacher education and curricula reported tons of issues related to ICT resources and facilities availability at all levels of learning throughout the world. In developing countries like Africa many programs were lunched to ensure provision and availability of ICT resources and materials in schools that included launching of e-schools Initiative in 2003 by NEPAD intended to equip all African high schools with ICT equipment including computers, radio and television sets, phones and fax machines, communication equipment, scanners, digital cameras, and copiers, among other things reported (Aginam, 2006). Other ICT-driven projects and policies for schools lunched in Africa included but not limited to, School Net Africa that covered 31 countries (FGN, 2006); One Laptop per Child (OLPC) in 2005 in Rwanda, Ghana, Mozambique, Senegal and South Africa; Mobile Internet Unit (Ajayi, 2003); United Nations Development Programme (UNDP) IT for Development; World Bank's WorldLink; Intel World Ahead Program that involved Nigeria and South Africa in 2003 (Adomi, 2005); Internet Initiative for Africa (IIA); Microsoft Partners in Learning Program, Connect-ED, Curriculum Net and many more. Sadly, upon all these and many more, the level of ICT resources availability compare to demands is still low and insufficient noted (Barteit et al., 2019; Nyanja & Musonda 2020).

3.2 Funding

Inadequate funding as one of the serious impediments to successful ICT integration in our schools (Aina, 2013). He wrote that the money needed for full ICT compliance is huge and this fund is not available because of economic situation of the country. Equipment like computers, projectors and internet facility are required; these materials are very costly to purchase by any school except there is external aids. Akindutire (2010) observed that Nigeria government has not met the UNESCO recommendations of 26% of the total budgetary allocation to education sector as reflected in her yearly budget. Therefore, funding seems to be among the serious issues that hinder ICT integration.

3.3 Professional Development

The role of professional development to the development of any organization or profession cannot be overstressed. Regular and continuous training and retraining of stakeholders in education industry is crucial and necessary since teacher is like a knife, he needs to be sharpened regularly. While there are many stakeholders involved in guarantee effective incorporation of ICT in the education, teachers have a predominantly important role to play. According to Carlson and Gadio (2002), teachers are the key to whether technology is used appropriately and effectively. Therefore, adequate, and relevant ICT knowledge, skills and utilization is paramount among teachers. Dauda and Samaila (2019) indicated that majority of Physics teachers have poor ICT knowledge and skills; they could not use Microsoft Excel and PowerPoint in teaching and learning process. Stephen (2013) also found that most Physics teachers are not computer literate. According to him a high proportion of over 70% Physics teacher had little or no computer literacy. The study further reported that there was no professional development such as ICT workshop, seminar or conference to improve teachers' capacity. This can be concluded that professional development will assist teachers to integrate ICT facilities into their classrooms, however, lack of ICT training or workshop slows down and hinders the integration of ICT in the schools.

3.4 Other Services

Other services represent fundamental needs in using ICT to facilitate teaching and learning in the classroom such as internet, power supply, and regular maintenance of ICT resources. Firstly, the availability of Internet service is still a challenged in developing countries and it affects development of educational institutions. The study conducted by Stephen (2013) that investigated availability, accessibility and utilization of ICT in secondary school Physics curriculum delivery in Akwa Ibom State, Nigeria reported that there were inadequate Internet facilities and most of the schools in the State were not connected to the Internet and hence Physics teachers have no access to the Internet for use in Physics curriculum delivery. This is one of the reasons that ICT integration was unsuccessful in Nigeria and until this issue is fixed the desired result might not be achieved. Next, regarding, power supply, a study conducted by Aina (2013) revealed that lack of constant electricity is a serious factor slowing integration of modern technology in teaching and learning in schools in developing countries. In addition, UNESCO-IS observed that the integration of ICT in schools requires electricity that is regularly and readily available. In many developing countries, however, rural, remote and nomadic regions are frequently neglected when developing national electrical infrastructure. Therefore, the teachers could hardly integrate ICT facilities into their classrooms and students enjoy less from multiple advantages of ICT. Lastly, maintenance where poor regular maintenance of ICT facilities has seriously affected ICT integration especially in African countries. This could be to be fixed by having qualified ICT technician who will help train the teachers and students, maintain ICT facilities and offer experts advice where necessary. Although, in developed countries the issue of maintenance (technicians) has been addressed for long but developing countries are still battling with limited and unprofessional numbers of ICT technicians. This led to the poor implementation of ICT across the schools.

4.0 Solution

This study highlighted the barriers that militated against successful integration of ICT in Physics education. However, teachers need system-wide support to implement ICT. This means that the schools, district, local community and state share with teachers a commitment to using ICT to support teaching and learning. In addition to that, the government should supply sufficient ICT teaching facilities to schools; facilities such as computers, computer laboratories, projectors, educational software and ensure all schools are internet compliance. The facilities should be well monitored to make sure they are not vandalized, misused or stole; this could be done by charging the school management with this responsibility. Furthermore, professional development should be emphasized. Successful ICT integration hinge on well- trained and motivated teachers. Therefore, ICT workshops, conferences and seminars should be conducted time to time and make its compulsory for Physics teachers to attend. The workshops should guide teachers on how to employ new media devices for teaching and learning; to create effective digital presentations using common tools for preparing slide shows, videos and podcasts; to develop confidence and ability to communicate using digital tools; to choose the most appropriate research tools and databases, and applies the most effective searching techniques; to produce useful and safe online resources in the classroom; and to capture and edit images, audios and videos. Those who refused to comply and attend workshops should be sanctioned and punished according to the law. ICT knowledge and skills should be among required qualification that any Physics teacher should posses before given a job to teach Physics. The in-service teachers with poor ICT knowledge and skills should be given a time frame (at most two years) to acquire necessary ICT skills or else should look for another job.

In addition, the Nigerian government should commit reasonable amount of funds for ICT tools and plan for sustainability. ICT changes too rapidly for schools to expect that one-time purchases of equipment or software will suffice. An ICT plan should allow for timely upgrades and maintenance in addition to keeping resources current and useful. The plan should identify a specific amount to spend each year and a prioritized list of activities to fund over the life of the plan. Funding should address both initial purchases and upgrades needed to sustain schools' technical capabilities over the time. All Physics teachers should have access to hardware, software and other resources needed. A personal laptop and unlimited internet access should be provided to the Physics teachers so that they can access information anywhere and at any time. This will not only increase teachers' digital skills but improve students' performance and ICT skills. The issue of inadequate electricity supply has been causing a serious setback in ICT integration particularly in African countries. Power generation must be seriously maintained because uninterrupted power supply is a factor that encourages technology integration.

5.0 CONCLUSION

The impact of Information and Communication Technology (ICT) has increasingly being recognized in almost all sectors of modern life, if it is carefully integrated in Physics education, it assists both teachers and students to easily access information and subsequently improve students' learning outcomes. The application of ICT is fundamental today in teaching and learning but there are many problems militating against its full application in Nigerian schools. However, there are problems challenging its integration, these problems are poor ICT infrastructure, lack of standard ICT policies, poor Internet and network facilities, poor power supply and lack of professional development program. These challenges could be solved if the government emphasizes professional development; organizes ICT workshops, seminars and conferences; provide adequate funding to secure modern ICT facilities; and provide constant power supply.

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