Innovations for Educational Resilience: The virtual laboratory as remedy for the teaching and conduct of practical work in science courses during unexpected occurrences.

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This paper focuses on the important role virtual laboratories could play in the teaching and learning of practical courses in sciences during unexpected occurrences such as that witnessed during the Corona Virus (Covid-19) pandemic of 2019. Covid-19 swept all over the world and its effect was quite important to the educational system. The whole world locked down and over 100 countries, which translate to over 90% of the world student's population, had to shut down schools. Governments of most countries and Institutions of learning had to embrace Distance Learning (DL), a method of imparting knowledge, characterised by the separation of the teacher and learner in space and/or time and other forms of eLearning platforms such as Zoom, Google Classroom, Canvas, Blackboard and Microsoft Teams as well as Google Hangouts, Cisco, WebEx and flipped classroom etc. for their populace. This was to forestall a total and imminent collapse of their educational systems. Science courses require hands on practical sessions which are of paramount importance for the understanding/internalisation of concepts and contents but this became impracticable due to the Covid-19 lockdown of schools. A remedy would be the usage of virtual laboratories, which are learning environments in which students convert their theoretical knowledge into practical knowledge by conducting experiments virtually by simulation of real laboratory environment and processes. Conclusively therefore, in the face of such emergencies, a practicable measure to be embraced by institutions, stakeholders in education and the government is the establishment of virtual laboratories, which could even become a permanent feature in the education sector post such emergency eras, especially in the developing countries of the world.

Keywords: Virtual Laboratory, Virtualisation and Digitalisation, Emergencies, Covid-19, Distance Learning.

Introduction

Ikpe (2014) is of the stance that advances in Information and Communication Technology (ICT) in the 21st century and its incursion into learning environment has brought about innovative ways of delivering instruction at a distance. This is exemplified in the usage of virtual laboratories for the conduct of practical works in science courses, thus making the assumption that laboratory courses can only be delivered in a face-to-face (f-2-f) laboratory setting contentious. Indeed Ndahi (2006) had earlier stated that advances in communication technology along with innovative methods of delivery of instruction at a distance have challenged the idea that laboratory courses can only be delivered in a face-to-face (f-2-f) laboratory setting. According to Ikpe (2014) institutions could take full advantage of the opportunities presented by the existence of virtual laboratories which is an online virtual experiment system based on web technology and virtual reality technology in providing learners with the desired hands on laboratory experiences in science courses.

Various scholars in the field of science and science education have harped on the important role of practical work in the teaching and learning of science courses. Saidi, Friesen & Al-Ezzah (2014) and Chan, Gerven, Dubois & Bernaerts (2021) informed that inasmuch as they could be expensive and time consuming, practical laboratory courses are an integral part of chemistry and invariably science education. They further stressed that the laboratory is where one could learn how to do science/chemistry. Hamed and Aljanazrah (2020) informed that laboratory work in physics as well as other natural sciences was a vital component for studying courses therein. Earlier, Bretz et al (2013) while driving home on the necessity of engaging in science practical activities asserted that practical laboratory practices increases the curiosity and positive attitudes of students toward science. On a similar footing, Hatherly, Jordan and Cayless (2009) and Ayodele (2007) had informed that engaging in practical activities in science courses is of utmost importance, as it does reinforce concepts learnt theoretically. What then is science practical work?

Definition of practical work

Dillon (2008) informed that an array of researchers and educators had in the past given different meanings to practical work in science. Terms used include; practical and enquiry skills', practical and investigative activities', independent enquiry and experimental work. Dillon (2008) harmonised these views by defining practical work as any "learning experiences in which students interact with materials or with secondary sources of data to observe and understand the natural world". Millar (2004) used the term 'practical work' to

refer to “any teaching and learning activity which at some point involves the students in observing or manipulating the objects and materials they are studying”. He preferred the term ‘practical work’ rather than ‘laboratory work’ because location Millar (2004) asserted is immaterial when considering this kind of activity. Practical work can take place either in a school laboratory or in an out-of-school setting, such as the student’s home or in the field. This notion is germane to this work as it puts to bed the appropriateness of interventionist measures like the use of technologically mediated environments such as the virtual laboratories for practical works. In the final analysis, Dillon (2008) defined practical work or activities in science as including any “learning experiences in which students interact with materials or with secondary sources of data to observe and understand the natural world“. So also, the British Science Community Representing Education (SCORE) recently defined practical work in science education as “learning activities in which students observe, investigate and develop an understanding of the world around them, through direct, often hands-on, experience of phenomena”(SCORE, 2013).

Theoretical Framework

The idea of the usage of virtual laboratories for science courses is rooted on the premise of the constructivists’ theory of learning. Constructivists are of the view that learners construct their own reality or interpret it based upon their perceptions and experiences, as such; an individual’s knowledge is a function of his or her previous experiences, mental structures, and beliefs which are used to interpret objects and events (Fox, 2003). The theory is attributed to Bruner (1960) and Piaget (1980) and is based on the idea that knowledge or concept is constructed by the learner based on mental activity. Constructivists are of the view that knowledge is internalised by the learner via the process of accommodation and assimilation and that learning occurs when it is situated, contextual, problem based, social and authentic (COL, 2003). This rationalisation was also towed by Nwosu (2003) who stated that with the constructivist model of instruction, students redefine, reorganise, elaborate and change their initial concepts through interaction among themselves and their environment. Thus from the constructivist perspective underscores the desirability of hands on practical experiences in the teaching and learning of sciences.

Conduct of Science Practical Work during Unforeseen Occurrences’

Situations may arise which could culminate in the disruption of academic activities in institutions of learning. One of such event was the advent of the Coronavirus (Covid-19) pandemic by the 31st of December, 2019 in Wuhan China. Daniel (2020) as well as Selwa, Mohamed, Hind, Abdelali, Driss and Larbi (2020) informed that Covid-19 was the greatest challenge ever faced by national education systems. They informed that the virus made radical changes from a part of the world to the entire world, with concomitant effect on healthcare, economy and education. Selwa et al (2020) further informed that as a result of it, the global educational system witnessed an unprecedented closure of institutions in over a 100 countries, this amounts to about 90 percent of the world’s student population.

Basilaia (2020) stated that in response to the Covid-19 pandemic, various countries globally had to adopt measures such as; online library supports, television broadcasts, video lectures and online channels. Importantly, Basilaia and Kvavadze (2020) stated that to increase the coverage of the school lessons to the populace, ministries of education the world over resorted to the live transmission of lessons through television channels in various subjects. Laboratory experiences as harped on by scholars such as Saidi, Friesen & Al-Ezzah (2014) and Chan, Gerven, Dubois & Bernaerts (2021) have always been an important part of any engineering or science curriculum. Hatherly, Jordan and Cayless (2009) had emphasised on the desirability and value of laboratory work for physics, just like all other science subjects. In Nigeria for instance, the National Policy on Education (NPE, 2013) Section 3, Sub-Section 38.2.1 highlights the government’s stance on the study of science courses and the important role of practical works in science at all levels of schooling. The teaching and learning of science in schools involves practical classes where hands on experiments are conducted on some concepts taught. In the normal school settings, practical work in science subjects are usually conducted physically in designated laboratories within the institutions, but with the total lockdown occasioning the emergence of Covid-19, it had become impracticable to conduct such practical exercises for the various science subjects and this begged for practical solutions. This article therefore sets out to establish that an avenue which could be utilized to remedy this anomaly is resorting to the use of virtual laboratories for practical work in science courses.

Virtual Laboratories

Going into the nitty-gritty or in-depth description of the technicalities and technological details involved in the operation of the virtual laboratory is beyond the scope of this delivery. However, it is pertinent to state according to Woodfield (2005) that a virtual laboratory simulates a real laboratory environment and processes, and is defined as learning environments in which students convert their theoretical knowledge into practical knowledge by conducting experiments. The researcher further informed that virtual laboratories have

been used to teach concepts such as thermodynamics, electronic circuits and a number of experimental courses in physics satisfactorily. It is noteworthy to state that computer animation and visualisation can help to illustrate complex relationships during classroom teaching as well as in individual learning at home. Ndahi (2006) had stated that people construct virtualized learning environment through web technology and computer communication technology and that the virtual lab is an online virtual experiment system which is based on web and virtual reality technology; it is the digitization and virtualization of laboratories on campus. So, it suffices to say that the virtual laboratory offers the users the possibility to share different resources out of time and space boundaries. It enables geographically separated users to effectively facilitate remote access to various presumably diverse (real) resources.

Much of science learning is hands-on, but there are instances when it is impractical or impossible for students to participate in certain science activities. When students are unable to engage in certain activities because of cost, time, safety issues, or accessibility, computer simulations can be an effective approach (Huppert et al., 2002). Simulations may take many different forms, such as micro worlds or virtual laboratories. These types of simulations are generally a software programme or online applet "with which children play and discover concepts and cause-effect relationships through exploration and experimentation" (Henderson, Klemes and Eshet, 2000). Laboratories have always been an integral component of science education. However, the rapid growth of Information and Communication Technologies (ICT) has now made it possible for virtual laboratories to be used as an alternative or to supplement the physical or real laboratories. Physical laboratories are the traditional laboratories found in universities; they occupy space, are well equipped and require expertise to function effectively

The virtual laboratory is an online virtual experiment system which is based on web and virtual reality technology; it is the digitization and virtualization of laboratories on campus (Ndahi, 2006). Below are screenshots of a typical virtual laboratory in chemistry.

Figure 1: Screenshots of a typical virtual chemistry laboratory. (www.google.com)

Figure 2: Screenshots of a typical virtual chemistry laboratory. (www.google.com)

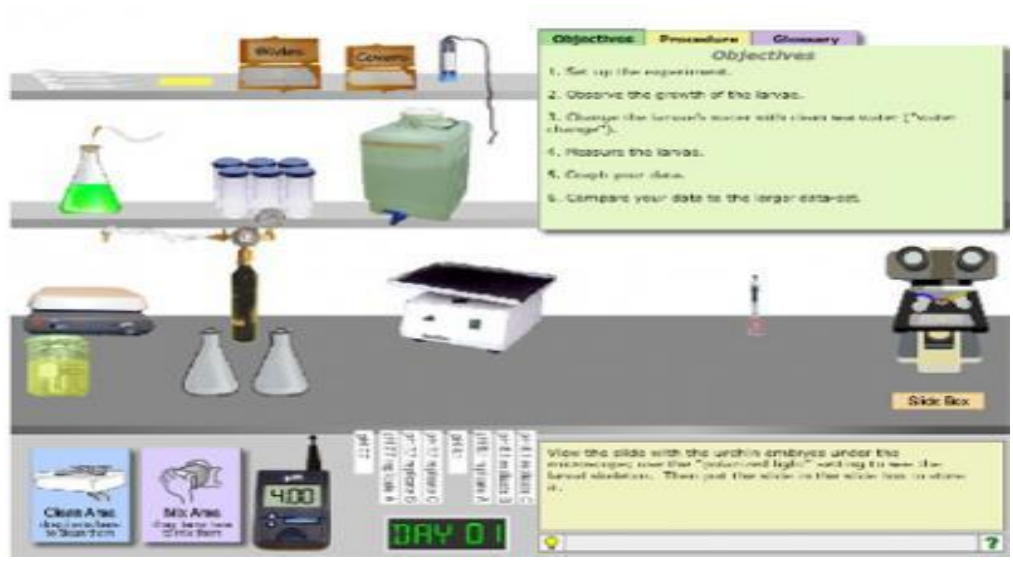

Figure 3: Screenshots of a typical virtual chemistry laboratory. (www.google.com)

Ikpe (2014) had stated that the emergence of virtual laboratories in science education is novel as it provides students with opportunities for enriching their learning experiences, as they could conduct experiments as if they were in real laboratories thereby improving their experiment related skills such as manipulating materials/equipment's and collecting data. Thus, with the virtual laboratory, it makes no difference whether a student is in a campus (in a traditional university) or at home (in a virtual university). Despite the observable advantage that may occasion the emergence of virtual laboratories in science education, it is worthy to mention some hindrances to its full utilisation particularly in developing nations of the world. Factors that could militate against the smooth usage of virtual laboratories in certain parts of the globe include; issues of low computer literacy and density, so also of low bandwidths and lack of dependable sources of power.

Advantages of Virtual Laboratories

This write up will be incomplete without mentioning some advantages ascribable to the usage or emergence of virtual laboratories in science education. Some of these include logistical benefits; this has to do with cost cuts, if number of beneficiaries is taken into account in view of space, instrumentation, and the necessary human support required. Indeed, Muthusamy, Kumar, & Latif (2005) asserted that the financial implication of setting up a virtual laboratory is very low compared to that of a real laboratory. Furthermore, they opined that operating and maintenance costs are also very low compared to that which will be incurred running

real laboratories. Unlike real laboratories, virtual laboratories do not require daily maintenance and expertise to function effectively neither are incessant replacements required for damages due to malfunction.

Ikpe (2014) did inform that Open and Distance Learning (ODL) system (as embraced during the Covid–19 pandemic) which is characterised by the separation of the students and their instructors/lecturers in time and space stand to benefit from the establishment/usage of a virtual science laboratory. Furthermore Ikpe (2014) expressed that traditionally and until very recently, lectures, tutorials and laboratory works in science education have always been delivered through the conventional face to face means. Ikpe (2014) is of the view that with advances in ICT, science education via ODL has become a reality, emphasising that laboratories are one of the principal ways science students do learn how to apply theoretical facts, concepts and principles. With the virtual laboratory, like all other ODL tools it has become immaterial whether a student is in a campus (as in a traditional university) or at home (as with virtual university). Thus the virtual laboratory gives unlimited opportunities to ODL students to conduct laboratory experiments without ever going to physical laboratories. Jonah (2007) and Ayodele (2007) also had earlier informed that virtual laboratories can be accessed from the internet at anytime, anywhere. Some observable disadvantages include low computer literacy levels especially with developing countries, absence of high-speed broadband internet connection, software updates and general acceptability of new products amongst users.

Summary and Conclusions

The role of practical work in the teaching and learning of science was highlighted in this paper. It is a known view that the best approach to the learning of concepts in science is by 'doing' i.e. using the manipulative skills as defined in the science process skills. Practical works at institutions of learning do take place in designated laboratories but situations may arise which will make this practically impossible. This is exemplified by the occurrence of the Covid – 19 pandemic during which period, institutions of learning were shut down all over the world. In the face of these types of unforeseen circumstances, resorting to the usage of facilities like the virtual laboratories becomes imperative. With the knowledge and advances already made in the field of technologically mediated learning, institutions can key into this by setting up virtual science laboratories. This will undoubtedly make available the highly desirable practical lessons in science courses, a prerequisite for the production of highly skilled and qualitative scientists.

Conclusively, the need for practical experience in the teaching/learning of science courses in education is of paramount importance. Situations may arise which could make the conduct of practical work in institutions infeasible. With the knowledge of the advances already made in the field of technologically mediated learning, institutions can take advantage of this by setting up virtual science laboratories which will make practical lessons available to students, by the incorporation of the virtual laboratory into its teaching arsenal, thereby making available the highly desirable practical lessons in science courses which is a prerequisite for the production of highly skilled and qualitative scientists. This conclusion is buttressed by the theory by Trindade, Fiolhai, & Almedia (2002) which stated that by maximizing interactivity, virtual laboratory applications render students active thinkers instead of passive observers and thereby construct effective and meaningful learning processes. As laudable as the idea of deploying virtual laboratories for teaching and learning of sciences in institutions during unforeseen circumstances maybe, there should be no losing sight of the fact that in developing nations, certain factors may be albatrosses to this noble innovation. These include issues such as low computer literacy and computer density, low bandwidths and lack of dependable sources of power in most of the developing countries.

Recommendation

Occurrences in the universe currently may defy definite and accurate predictions, wars may broke out, pandemics may set in and a host of other such unforeseen developments. These could culminate in the disruption of daily activities in places of learning or work etc. Practical work in the teaching/learning of science could be disrupted by such incidences. It is well established that one remedy for such is to resort to the usage of virtual science laboratories. It is therefore appropriate to recommended that governments, institutions of learning and other stakeholders in the education sector should key into the development or establishment of virtual laboratories in science so as to checkmate such emergencies. Such laboratories can also be maintained as a permanent feature in the institutions.

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