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FOREWORD

I warmly welcome all and sundry to the volume 3 issue 1 of Federal Polytechnic – Journal of Pure and Applied Sciences (FEPI-JOPAS) which is a peer reviewed multi-disciplinary accredited Journal of international repute. FEPI-JOPAS publishes full length research work, short communications, critical reviews and other review articles. In this issue, readers will find a diverse group of manuscripts of top-rated relevance in pure and applied science, engineering and built environment. Many of the features that you will see in the Journal are result of highly valuable articles from the authors as well as the collective excellent work of our managing editor, publishing editors, our valuable reviewers and editorial board members.

In this particular issue, you will find that Joseph and Adebanji provided innovative technology on light traffic control system. Ogunkoya and Sholotan engaged standard method for microbiological assessment of shawarma from Igbesa metropolis for possible microbial contamination. Ilelaboye and Kumoye unveiled the effect of inclusion of different nitrogen source on growth performance of mushroom. Ogunyinka et al utilized Fletcher Reeves conjugate gradient method as a robust prediction model for candidates' admission to higher institutions. Omotola and Fatunmbi examined the impact of thermal radiation with convective heating on magnetohydrodynamic (MHD), incompressible and viscous motion of non-Newtonian Casson fluid. Aako and Are meticulously investigated factors affecting mode of delivery using binary dummy dependent models. Abiaziem and Ojelade successfully synthesized biologically active silver nanoparticles using *Terminalia catappa* bark as the eco-friendly source.

In addition, Olowosebioba et al. assessed the rectifying effects of various diodes in power supply units using multisim circuit design software programme. Olujimi et al. successfully accomplished the use of fingerprint based biometric attendance system for eliminating examination malpractices with enhanced notification. Alaba reported the nutritional status assessment of school age children (6-12 years) in private primary school in Ilaro. Muhammed-lawal et. al. assessed the execution and effect of corporate social responsibilities and return to marketing. Awolola and Sanni's research was about achieving quality of engineering education and training in Nigeria using Federal Polytechnic, Ilaro as the case study. Oladejo and Ebisin expatiated on virtual laboratory as an alternative laboratory for science teaching and learning.

Finally, Aneke and Folalu investigated the prospect and problems of the hotels in Ilaro, Ogun State.

I would like to thank and extend my gratitude to my co-editors, editorial board members, reviewers, members of FEPI-JOPAS, especially the Managing Editor, as well as the contributing authors for creating this volume 3 issue 1. The authors are solely responsible for the information, date and authenticity of data provided in their articles submitted for publication in the Federal Polytechnic Ilaro – Journal of Pure and Applied Sciences (FEPI-JOPAS). I am looking forward to receiving your manuscripts for the subsequent publications.

You can visit our website (https://www.fepi-jopas.federalpolyilaro.edu.ng) for more information, or contact us via e-mail us at fepi.jopas@federalpolyilaro.edu.ng.

Thank you and best regards.

E-Signed
Prof. Olayinka O. AJANI

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Virtual Laboratory: An Alternative Laboratory for Science Teaching and Learning

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Abstract

The challenges that face our educational system today can be traced to inadequate funding which is now being contested by growing demands for education at different levels and in every part of the nation than ever before. Most conspicuous of these accumulated and mounting glitches is the lack of or inadequate learning facilities. This study observed the state of learning resources in our schools most especially the Science and Technology speciality reminiscence of inadequate funding of laboratory. There is need to provide an education that takes learners beyond reading and writing to acquisition of skills and attitude development that enable young scholars to learn, unlearn and relearn as the need arises through the provisions of new computer technologies such as virtual laboratory. The study explores reports of empirical studies on the use of virtual laboratory as a viable alternative and complementary mode to the traditional physical laboratory. The conclusion drawn asserts that virtual laboratory is truly capable of providing learners with the learning benefits that accrue from laboratory activities with less cost and risk. This study recommends that proprietors at all levels should embrace this new learning platform to provide a long-lasting remedy to the dearth created in the laboratory skills of our students.

Keywords: Hands-on activities, Learning resources, Traditional physical laboratory, Virtual laboratory, Wet-labs

INTRODUCTION

The whole essence of teaching–learning exercise at any given time is to bring about meaningful learning experiences. In an instructional process, where the instructional system is the teacher's arena and the learner is the focus (Nwaboku and Akindoju, 2003), every exercise is directed towards achieving a particular or set of predetermined objectives. Actual realization of these objectives depends largely on a number of factors which principally include the learners, the teachers, the content and the learning resources among others. These factors, as essential components of an instructional system work together as a whole under principle of General Systems Theory for efficiency and to produce the intended outcome (Emergent Property). Any alteration, malfunction or inefficiency of any of these components, affects the overall performance of the system. Today, our instructional systems at all levels face daunting challenges that are products of inefficacy of the various components of the system. Very poor teacher-student ratio (particularly in the public schools), infrastructural deficit, inadequate school facilities, unavailability of learning resources and poorly motivated learners are the most obvious of our challenges.

The yearning and demand for education at all levels is on the increase and to sustain the chronicles of Millennium Development Goals (MDGs) in providing access to education for all citizens, these challenges must receive prompt attention capable of making significant improvement in all of the components of our instructional systems and obviously, no one solution fits all. However, learning resources appear to be at the centre of it all, teachers need them to aid their teaching and learners need them to aid their learning particularly in the sciences. Of the learning field in our schools (secondary and tertiary), the field of Science Technology & Mathematics (STM) seem to be most vulnerable with respect to lack of or inadequate leaning resources.

This paper is to bring to limelight the learning benefits that accrue from the use of virtual laboratory as learning resource in science, particularly for practical tasks that ordinarily takes place in the traditional physical laboratory. It also showcases virtual laboratory as a viable alternative to overcoming the challenges or limitations of the traditional physical laboratory which borders around unavailability or inadequate facilities, lack of consumables, inaccessibility by learners, late or in exposure of learners to practical as and when due, laboratory hazards and lack of personnel among others.

Review of Existing System

Science learning proselytizes activity-based and hands-on experiences which are not readily provided in our schools. It is almost irrefutable, that not less than six out of every ten students in the field of Science and Mathematics in most of our Senior Secondary Schools particularly those in class two and three will fail simple burette reading test not to mention carrying out basic titration experiment while some are as worse to the point of being unable to identify basic laboratory apparatus or state their uses (Oladejo, 2018).

Sciences are taught as if they are all abstract and what that pose to learners in most cases is that this field of knowledge is a very difficult one. In most of our senior secondary schools, virtually all cases of laboratory preparation of common elements like hydrogen, oxygen and nitrogen ends with talk and chalk exercise, the case is the same for biology and physics and all these content units form the basis of questions in terminal examinations such as West African Senior School Certificate Examination (WASSCE). The resultant effect of this reflects clearly in the lack of confidence in our students to take examinations independently. It's happening all around us! Schools are built without adequate provision for learning resources. No libraries, no laboratories, where they exist, they are either in appropriate to students' ratio and or poorly equipped, poorly maintained and old modelled (Akinola and Oladejo, 2020; Okebukola, 2020).

Chemicals are not so cheap neither are the laboratory equipment, glassware are bound to break, laboratory hazards can occur and students are bound to make series of trial and error using consumables before coming on point. All these truly, can be very expensive to keep up with as expected. For many developing nations including Nigeria, meeting educational needs is complicated by limited financial, material and human resources, accelerating demand for education at all levels, persistence poverty and equity concern (Rusten, 2003). Records have it that many developing nations (particularly in Africa) do not commit sufficient fund education from the nations' annual budget as most nations manage to roll between 7% and 18% of their annual budgetary allocation on education (Ige, 2016). A case of Nigeria (Africa's largest economy) and other African countries are shown in figure 1 and table 1.

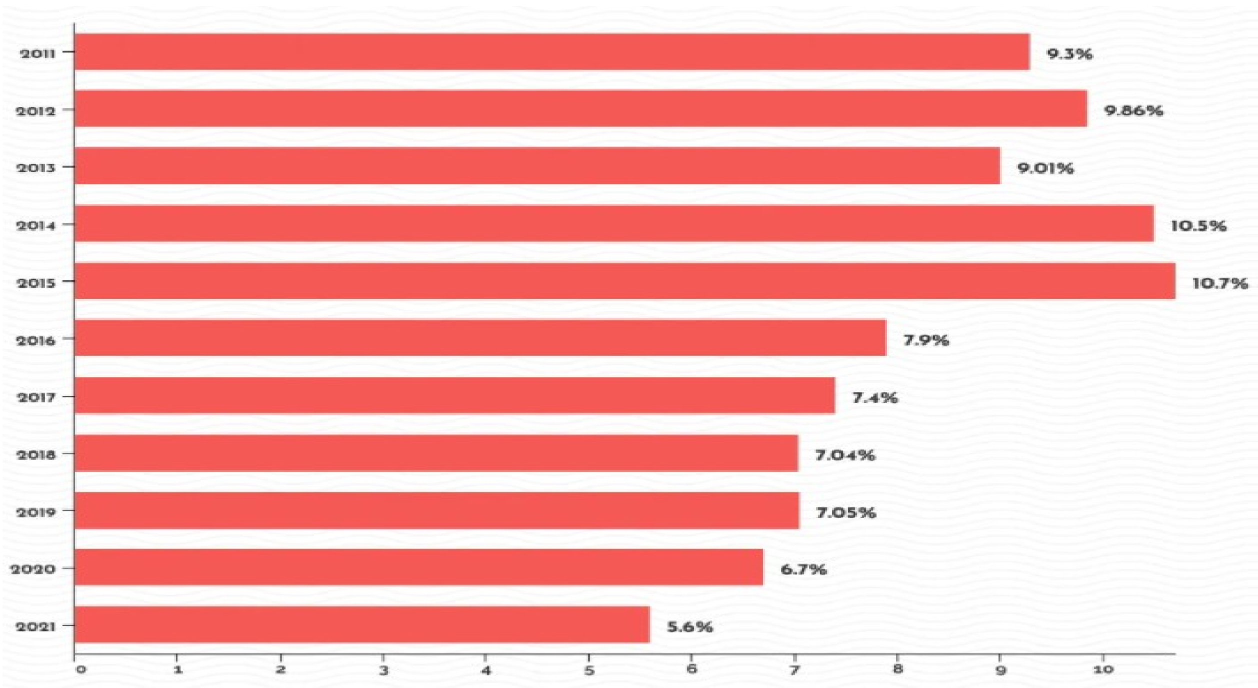

Figure 1: Trend analysis of Nigeria budgetary allocation on education from 2011 – 2021
Source: Premium Times (2021)

Table 2: Annual budgetary allocation for other African countries (Otive, 2017)

Countries	2010	2011	2012	2013	2014
Burundi	16.59 %	14.98 %	16.43 %	17.24 %	-
Benin	-	-	25.02 %	22.34 %	22.23%
Ethiopia	26.30 %	29.67 %	30.54 %	27.02%	-
Madagascar	-	19.78 %	20.33 %	13.99%	-

The state of education in Nigeria largely explains the high level of underdevelopment in the country. School structures are dilapidated, infrastructures have collapsed, population is increasing, teacher supply and quality are declining, and poor method of quality assurance within the education industry up to tertiary institution are major challenges (Gbenu, 2012). More terrible is the issue of incessant change in curriculum structure and content (with poor research basis and poor or non-pilot studies), subjecting the life of the learners to undeserved experimentation. Millions of children and young adults are not in school, those in school are not getting the ideal education and there is a high rate of illiteracy and poorly schooled young minds in the society especially in the very rural areas in the country. The greatest challenge to the country in this century is making our large rural illiterate community literate, especially in science education (Onifade, 2006).

However, the fact which confronts us at time is that literacy has gone beyond reading and writing using paper and pen, as stated by Alvin Toffler, the illiterate of the 21st century are not those who cannot read and write but those who cannot *learn, unlearn and relearn* and the ability to do this is embedded in Glavert (1996) which expresses the acquisition of *physical skills* (use of tools), *social skills* (able to cooperate with others), *process skills* (able to offer explanation), *attitude* (persistence in solving problem) and *conceptual development* (understand that some changes are irreversible) as the five significant categories of achievement in learning particularly in the sciences. Schools ought not to remain mere venues for the transmission of prescribed set of information from teacher to student over a fixed period of time, rather, schools must promote learning to learn which entails the acquisition of knowledge and skills that makes possible continuous learning over a lifetime.

The world is changing fast, nations are developing at rapid rate and functional education; science and technology is the obvious secret. We cannot continue to accept educational outcomes that reflect wide discrepancy between the set goals highlighted in the 6th edition of our National Policy on Education and actual accomplishments. It is time to adopt fresh approaches that are relatively affordable, potentially viable, sustainable and relevant to the nature and needs of today's learners and the modern global economy. One of these approaches is the use of new computer technologies in the classroom to support and enhance teaching activities and learning outcomes.

Technology Enhanced Learning

Virtually every form of technology, old or new, simple or sophisticated can be used for the purpose of classroom instruction and today, there are numerous types of technology employed in the classroom for the purpose of learning ranging from mono-sensory to multisensory gadgets. Wadi (2008) noted that technologies differ in their properties, scope, and potentials. Different technologies can be used for different purposes and their potentials are influenced by what we use them for. There are different levels at which technologies may be used, it includes presentation of a piece of information, demonstration of a concept, idea, phenomenon, law, or theory, drill and practice to gain competence in applying knowledge, research for certain topics or projects using multiple sources, interaction-manipulation of variables to reach generalizations or to draw implications from a law or theory, collaboration on projects with other students in the school or in other schools in the country or elsewhere or with scientists in the field and production of educational materials (UNESCO, 2002).

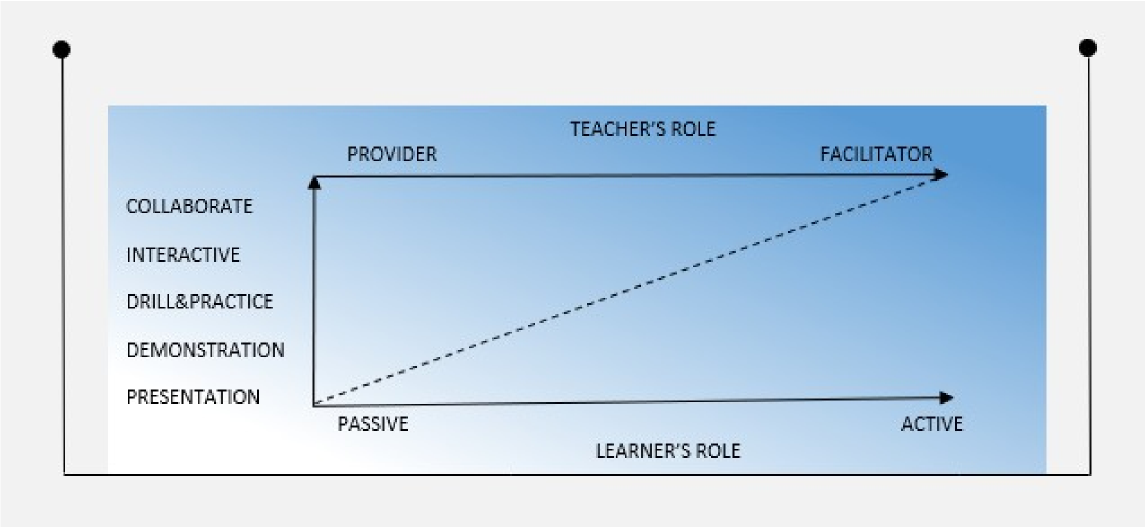

Figure 2: Use of ICT for different roles of teachers and learners (UNESCO, 2002)

The potentials of new computer technologies to significantly enhance learning and teaching are the most important reasons for introducing computers into schools and integrating them into all aspects of education. Information communication technology (with computer as hub) promotes interactivity and give learners better opportunity for in-depth learning, integrating digital approaches into learning system as the new strategy place control of learning more in the hand of learners (Nwaboku, 2006) and thus, helping to build professional learners by enhancing learning autonomy. In recent years, many scholars have studied the influence of computer technologies on how people think and likewise neurobiologists have also investigated the possibility that there is a relation between the learning capabilities (information processing) of young once and use of technology (Selwyn, 2011).

The general interpretation of findings from these studies shows that learners learn and retain information better with the use of computer technologies. One obvious reason for this is that computer (digital) technologies readily support the nature of todays' learners. It speaks the language which they understand best - *digital language*, conform to their personalities – *instant gratification*, and providing them access to cognitive capabilities beyond their innate capability through *digital wisdom* (Prensky, 2001a; 2009 & 2011). Functionally, computer technologies are used in teaching-learning process as instructional media, to make up for the deficiencies of the traditional instructional approaches with respect to cost, time, place, speed, consideration for individual differences and overall efficiency.

Information technology has provided new innovations to sustain constructing artificial educational environments by means of computer. Certain artificial environments such as simulations and virtual reality which are sophisticated educational technology sometimes go beyond natural environment. With the increasing popularity of virtual educational technology globally, the development of virtual learning environment became an important field of science which has its own basis and principles (Huda, 2011). The emergent of virtual technology as made possible the creation and availability of new and functional learning environment relevant to the field of science such as virtual laboratory.

Virtual laboratory as a solution to the limitations of traditional laboratory

Learning science requires detailed hands-on activities that take place in the laboratories – investigating procedures, observing phenomenon, manipulating objects, taking precise measurements, recording and reporting outcomes and drawing inferences are tasks that learners get engaged in in the traditional physical laboratory. However, there are logistical constraints, more especially relating to the funding and peculiar but not limited to developing nations that place significant limitations on the abilities of schools to offer high quality practical experiences to learners. The number of experiments carried out in schools and universities is usually limited due to safety reasons, lack of adequate infrastructure, equipment, due to limitations of time and space, and also due to poor precision in the implementation of experimental exercises (Sokoutis, 2003).

The world needs young people who are skilful in and enthusiastic about science and who view science as their future career field. Ensuring that we will have such young people requires initiatives that engage students in interesting and motivating science experiences. Today, students can investigate scientific phenomena using the tools, data collection techniques, models, and theories of science in physical laboratories that support interactions with the material world or in virtual laboratories that take advantage of simulations (de Jong, Marcia & Zacharias, 2013). The virtual laboratory is an electronic environment where experiments are being carried out without the full physical laboratory equipment (hardware, glassware and consumables) and hence obtaining the similar results and sometimes beyond. It is a laboratory that isn't real but emergent. It enables learners to link between theoretical and practical aspects without papers and pen. The virtual laboratory is a simulated version of the real lab, a learning facility that is designed for doing what scientists do in the physical laboratory; to perform and test experiment and to investigate procedures.

The virtual laboratory creates opportunities for students to enhance their scientific knowledge when equivalent wet-laboratory programmes are not available or affordable. If designed well, a virtual learning environment provides a broad range of opportunities for large, diverse student cohorts with different levels of experience in the subject matter and or different learning style (Krause & McEwen, 2009; Stuckey & Stuckey, 2007). A virtual laboratory brings many advantages, students can perform dangerous experiments without endangering themselves. Simulations are relatively affordable. Once developed, they can be done at no extra cost as many times as one would like. The results are always the same. A virtual laboratory allows for independent or collaborative work which is not necessarily only related to the lesson, school laboratory or available chemicals, and laboratory equipment (Nataša & Branka, 2015).

Learners have the advantage of repeating an experimental exercise as many times as possible until mastery is attained. Results are usually recorded and kept, giving the teacher and the learner opportunity to monitor progress path, reflect upon previously made mistakes and compare and share learning experience with other members of the class. Unlike traditional physical laboratory, virtual lab offers a distinctive level of interaction. Hence, it is considered to be a new model of computer-based learning that provides the individual learner with a wider range of scientific vision. This kind of educational technology provides an advanced individualized learning perfectly meets the nature of today's learners and their educational needs as it provides a high level of flexibility and freedom from constrains of time and place (Barbour & Reeves, 2009).

In the developed world, where the traditional physical laboratory is available and adequately furnished with state of the heart facilities and equipment, virtual laboratory is employed as learning tool to prepare the beginners and get them acquainted with the guiding principles of laboratory activities. Learners become familiar with apparatus and their uses, learn safety precautions and become ready for further activities in the wet lab. This safes time when learners are introduced to wet lab activities as they already are familiar with apparatus and are able to locate them easily, it reduces cost as wastage and damage are significantly reduced and also helps in preventing laboratory hazards as learners are able to take necessary precautions where and when needed. All these are true for the developing countries as well, where the traditional physical laboratory is either not available or ill-equipped and student-teacher ratio is not but poor, and most importantly, it helps to bridge the existing gap between theories and practical.

The virtual laboratory experimentation could break the limitations such as cost, time, place, and equipment quality, and students could perform experiment in a safer and reliable environment, with fewer worries and larger freedom, which could effectively strengthen learner's study interest and ability to analyse and solve problems. Virtual experiments could potentially allow students to improve their skills in deductive reasoning, hypothesis formation and testing, applying and testing scientific methodologies, recording, reporting and interpreting data as effectively as through real experiments. Virtual learning (through the use of virtual labs) also allow students to pleach two or more new teaching and training technologies such as LORE (which allows for *interaction* as learners take on their tasks), STUDYBLUE (which help students to create and keep electronic flash cards to induce *reflection* on key findings/notes particularly after class) and SNAGIT, JING or CAMTESIA (to capture students activities for *reflection, repetition and sharing*) together in order to strengthen learning outcome.

Findings on virtual laboratory affirm that the use of virtual laboratory, allowing virtual experiments to be undertaken, would help students to achieve these skills which are the basic functions of laboratory activities (Lavanya, Ramachandran & Divya, 2010; Mosotho & Mamonts, 2014; Nataša, Branka & Dejan, 2016). Banking on these enviable potentials and advantages of virtual laboratory and experimentation which include portability, safety, cost-efficiency, availability, recency, acceptability, minimization of error, amplification or reduction of temporal and spatial dimensions, and flexible rapid data display and proven positive impact on students' evolving skills, attitudes and conceptual understanding, virtual laboratory can be regarded as an unavoidable learning tool for sciences particularly in the developing nations where the challenges facing the educational industry are daunting and needs urgent attention (viable and long-lasting remedy) through any means possible.

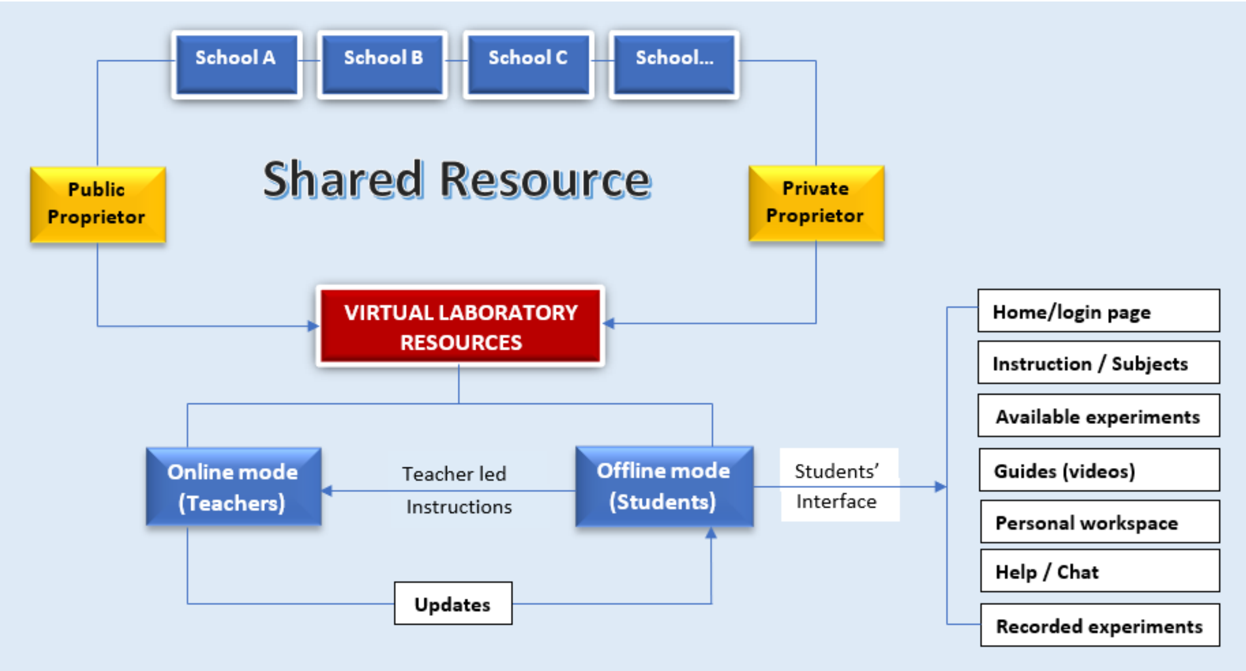

Figure 3: Shared resource virtual laboratory

Shared Resource Virtual Laboratory – A proposed model for secondary schools in Nigeria

On the basis that one of the contextually mitigating factors against the traditional laboratory in secondary schools in Nigeria is cost and the construction of a virtual lab also comes with an initial substantive cost. This model of virtual laboratory presents a unique option for schools/proprietors to collaborate and share resources to provide a rich learning environment/resource for learners at the secondary school level. The authors suggest that more than three schools can put available resources together and build a virtual laboratory. The laboratory may be subject-based (that is, chemistry, physics and biology) or multipurpose. In this model, it is multipurpose but sectioned into subjects.

Teachers of the collaborating schools serve as the resource persons (no need to hire), they (guided by the school curriculum) provide for the lab-designer the contents to input. One of the advantages of this model is that it allows the schools to populate the laboratory in bits using the ***available experiments feature***. The laboratory model offers two modes; the online mode which is for the teachers to prepare, teach and update contents; and the offline mode which is designed for the students to practice and gain mastery after an engagement with the teacher. While the online mode is for the teachers, students can also have access to it but only with the permission of the teacher. Using the online mode, the teacher invites the students for a practical session, engages them and instructs them to further practice and complete assignments using the offline mode.

The offline mode, except during an update, will consume no data (no internet charge), it allows available experiments to be repeated as many times as possible. It will be downloadable at most app stores, Google play store and Microsoft store in particular. Students can save a completed experiment, get immediate feedback and take short quizzes after any experiment. Every student will have a login detail which will be required to allow exploration of the learning resource. The home page of the laboratory will be designed with badges of participating schools and images of selected students for the schools. Once the student is logged in, the general laboratory rules and guidelines pop up. He/she then selects the subject of choice, upon successful selection, available experiments in the chosen subject also pops up for the student to select.

Welcome to the ***Shared Resource Virtual Laboratory*** is the message that takes the students into the main lab where the workbenches are well-designed with lab fitting just as in the real laboratory. Apparatus shelves are seen on the walls of the lab with labels, the reagent shelves are also filled with samples of reagents for use and demonstrations. Every student has an opportunity to create a personal workspace where s/he perform experiments. The advantage of the personal workspace is that it offers the student access to apparatus and reagents which have been pre-selected for intended experiments. For example, in my workspace, I may have an already set-up retort stand with burette for my volumetric analysis experiment, so, I need not spend time on the set-up again whenever I need to repeat or perform an experiment that requires a retort stand with burette.

Just as there are short quizzes at the end of every experiment, so is a detailed and self-explanatory guideline on how to perform any chose experiment. In some cases, the guideline will also include a short video of the experiment to be performed. The video affords the students the confidence to take on any available experiment even before the subject teacher's guide, after all, no physical hazard can result from any mistake made. The design of the lab is so sophisticated that possible outcomes of an error made in the traditional laboratory will also be experienced virtually. For example, if an overheating of a test tube is expected to break the glass in the physical lab, it will also get broken in this model, virtually.

For the first session, the offline mode of the laboratory gets updated at least three times (within the holiday, before the commencement of a new term). Thus, it is expected that within a full school year, the laboratory would have been fully equipped with the required experiments for a secondary school student in Nigeria, in three main science subjects. Another great and unique feature of this model is ***team teaching***. During an online session, a teacher of a particular school may seek the pleasure of a colleague from any of the participating schools to attend his or her lesson and contribute to discussions in order to enrich the learning experiences of the students.

The ***recorded experiments*** feature is available in both the online and offline mode. When teachers engage students in any experiment using the online mode, the session is automatically recorded. The recordings can be shared with the students to watch and re-watch, this will strengthen the acquired information in such lesson. It also allows students who missed the class to catch up with their colleagues. In addition, it also serves as feedback for self-reflection/assessment for teachers. It tells the teacher what and where he/she has done well and areas of need for improvement.

CONCLUSION

Virtual reality applications offer students unique opportunity for experiencing and exploring a broad range of environments, objects, and phenomena. Students can observe and manipulate inaccessible objects, variables and processes. These interactive technologies can present visual representations of physical phenomena to allow students to construct relations between scientific theory and empirical evidence and exploration. Through visual representations, virtual experimentation allow students to form mental models of observed phenomena, afford them the pleasurable attribute associated with visuals and thereby enhancing retention through good learning – a learning that helps students collaborate and discuss ideas for possible solutions, one that connects learners with one another within and beyond the walls of the classroom on curriculum content and immerse learners in a learning experience that allows them to grapple with learning tasks, strengthening their processes of inquiry, gaining higher-order thinking and problem-solving skills from pursuing solutions.

Recommendations

For effective utilization of virtual laboratory and realisation of the intended goals, we recommend that the proposed model of virtual laboratory should be embraced. The model took into consideration some of the limitations associated with earlier designs of virtual laboratory. We suggest that schools within a locality should put resources together (human and non-haman) to employ the services of programmers to build and design virtual laboratory with content details and usability features that best suit the need of their learners. We also recommend seminars and workshops should be organized for in-service science teachers to get them acquainted with the use of new teaching and training technologies such as virtual tools for experimentation while teacher training institutions should endeavour to equip pre-service teachers with the knowledge of these technologies for classroom activities. Above all, proprietors and school managers should embrace this new learning platform to provide a long-lasting remedy to the dearth created in the laboratory skills of our students.

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