Virtual Chemistry Laboratory: A Panacea to Problems of Conducting Chemistry Practical at Science Secondary Schools in Nigeria

Faruku Aliyu, Corrienna Abdul Talib

Abstract:- Laboratory activity as an integral part of learning chemistry provides students with a learning experience built up through student's interaction with concrete material is deficient in science secondary school students in Nigeria. This unpleasant situation resulted from the fact that, in many schools, laboratory personnel and facilities are either partially available or not completely available. This paper discussed some of the benefits of a virtual chemistry laboratory and how its three-dimensional interactive nature would be used to overcome these problems in order to enhance students' understanding and achievement in chemistry through the integration of the virtual chemistry laboratories in conducting chemistry practical. The paper further suggested for the integration of virtual chemistry laboratories or even support the real laboratories with virtual ones, particularly in schools that lack equipped chemistry laboratories in Nigeria.

Index Terms: Virtual chemistry laboratory; problems; panacea; chemistry practical; Science Secondary school.

I. INTRODUCTION

The primary source through which scientific knowledge, skills, processes and experiences are acquired is investigation and experimentation which mostly take place in the laboratory settings. For more than two decades ago, information and communication technologies get their way into almost all sectors of human endeavour including education. In science education, many concepts that are abstract in nature and can only be taught theoretically with some basic assumptions and misconception in the mind of students are now taught practically with the aid of technology [1]. Chemistry has been one of the science subjects with these abstract concepts such as the atom, molecule, molecular structure and bonding also benefited from the development. According to Tatli and Ayas [2], chemistry is one of the science subjects that contain a lot of abstract concepts which eventually cause serious misconception among students and the problems of conceptualization to the teachers. However, learning with the use of virtual reality offers unique affordance and experience in acquiring and constructing knowledge. It simplifies training involving dangerous experiments. Virtual reality environment is a technology-based simulated environment that permits real-time interaction virtually [3]. In the context of chemistry practical, the virtual reality environment, where the user is immersed within the virtual world to carry out the experiment is regarded as a virtual laboratory. Example of this environment is Oculus Rift [4]. Also, in the virtual environment, there exist the actual sculpting similar to the real-world environment. Precaution and safety measure with respect to dangerous experiment in the laboratory can be demonstrated using a virtual laboratory environment [4]. In a virtual environment, the user is provided with a dynamic interaction and increased immersion. This is achieved through gesture implementation and mimic nature of human body movement [5]. In the virtual chemistry laboratory environment virtually enabling them to access storeroom, preparation room and working desk and any other necessary facilities. Virtual environment assisted in the investigation [6]. The Virtual environment has been identified as a learning environment with vast opportunities in training learner practical aspect of science since it provides a 3D environment that enables the learner to interact with the object as in the real environment. Learners feel presence because they are immersed within the environment [7]. It provides a variety of benefits such as 3D graphics, immersion and interaction [7]. Virtual reality support self directly directed training because allow users to practice alone at his/her convenient time. He has the full control of zooming, reviewing, pausing which give him a feeling of presence.

A virtual laboratory is generally regarded as any computer-based on technology supported environment where interaction between the learner and experimental facilities takes place with the intention of observing and testing a hypothesis for confirmation or generating new knowledge. In this kind of environment, the control of an apparatus and other experimental procedures and steps are in the hand of learner virtually [8]. A virtual laboratory is a technology-based educational tool that can effectively provide learning with almost all the features of real laboratory for experimentation [9]. Virtual laboratory in chemistry practical has the potential of enhancing students' practical skills in analytical chemistry. This form of technology is currently gaining popularity in schools for conducting chemistry practical [10].

Practical chemistry, on the other hand, is an activity that involves students to either work independently or in a group in the laboratory or any place specifically assigned for carrying out an experiment and make an observation or

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manipulation of the real object and phenomenon. Conducting practical in chemistry is necessary bearing in mind that, the subject aims at understanding the chemical composition, nature, properties and transformation of matter [11]. In conducting practical, all five senses are involved in the observation and manipulation of the processes. These practical knowledge and skills are found to impact positively on students' attitude and achievement in chemistry and all other science subjects. Hofstein & Lunetta [14] argued that the essence of practical activity in chemistry is enhancing students' motivation and interest, understanding scientific concepts, developing practical and solving skills, inculcating scientific mind and habits and appreciating the basics and principles in science. Regarding the significance of practical in chemistry, In the Nigerian context, every final year science secondary school student is expected to write and pass chemistry subject in the Senior School Certificate Examination (SSCE) in which practical chemistry amounts to at least 35% of the overall assessment. This requirement makes it clear that the practical lesson is an integral part of chemistry and is expected to be learned by students of chemistry.

Despite this significance of practical chemistry, developing countries are commonly characterized by a poor standard level of education which resulted from many factors, including limited budget to education, lack of trained and skilled manpower and inadequate facilities. The situation is more common in the developing countries where the meagre amount of money allocated normally to education cannot cater to even 30% of what is required [13]. In Turkey, many state schools were reported to conduct chemistry practical only in rare cases or during students' final examinations due to insufficient laboratory equipment or complete absence of laboratory in a school [14]. In Nigeria also, many secondary schools are not enough and lack appropriate laboratory facilities which lead to a lack of basic practical skills and experience. Hence, the laboratory conditions in most of the science secondary schools generated a negative attitude and low academic achievement among science secondary schools' students. These persistent problems lead the researchers to embark on presenting virtual laboratory chemistry as an alternative strategy for conducting chemistry practical, particularly in schools that lack standard real chemistry laboratory.

II. LITERATURE REVIEW

The available literature revealed that developing countries including Nigeria are still battling to provide effective strategies of teaching chemistry and other science subjects due to insufficient laboratories and laboratory equipment. Chemistry students have consistently recorded poor academic achievement in the Senior Secondary School Examination (SSCE) for many years, which is an indication that there must be problems with the current practice and how it is taught [15]. Highlighted in the chief examiner's report of the National Examinations Council [16], students' achievement in chemistry was poor and many students lack basic knowledge and skills in the practical aspect resulting in their failure to respond to questions assessing their practical skills in chemistry. The lack of knowledge and skills in practical is attributed to inadequate laboratory facilities. According to Shamsuddin et al, [17] in their research solving problems of chemistry education in Nigeria, identified inadequate manpower and facilities as part of the major problems associated with learning chemistry in Nigerian secondary schools. Emendu and Okoye [18] reported that about 80% of public secondary schools in Anambra state, Nigeria lacks standard laboratory for chemistry practical and 88% of those with laboratories have no qualified laboratory technicians/attendants. Hence, they recommended for government's urgent intervention to make the learning of chemistry feasible. In another narration, Abudu et al [19] stated that most of the secondary schools in Ogun state, Nigeria has no enough facilities for conducting practical and other instruction in chemistry. However, due to financial constraint, many secondary schools in Nigeria cannot afford to establish and maintain a standard chemistry laboratory for experimentation of various concepts.

Virtual reality, on the other hand, is believed to have been in existence since the 1960s when Sutherland attempted to explain VR as a technology that allows the user to look, feel and listen in the virtual world as real [20] even though the commercial tool was not available till the 1980s [21]. According to Okechukwu and Udok [22], two major components were normally used in designing and building an effective virtual reality laboratory. They comprise of hardware such as computer workstations (i.e. PC), sensory display, tracking device, and process accelerator, and software such as 2D and 3D modelling, graphic, simulation and digital sound software.

There are many scholars that examined the effectiveness of virtual chemistry laboratory in conducting chemistry practical in many parts of the world. Ali et al [13] designed and developed virtual chemistry laboratory and tested it on their students with some experiment. The discovery made was that virtual laboratory in chemistry practical is effective and efficient, making students excited. In China, for example, an empirical study conducted by Su [23] on the sustainability innovation experiential learning model in virtual reality chemistry laboratory at a secondary school using survey design and questionnaire as an instrument. The study discovered that the virtual laboratory system of conducting practical chemistry affects motivation and self-efficacy of students in the course of learning. Hence students' feel interested and engaged in carrying out practical in the virtual chemistry laboratory. The study suggested that even if the students are going to do the practical lesson in the real laboratory, there is the need for them to at least view the procedures through the virtual laboratory in order to be familiar with the real processes involved. This will greatly reduce the possibility of accidents as some of the chemical experiments are dangerous and require a lot of care and precautions. In a similar vein, Tatli and Ayas [24] studied students' academic achievement in chemistry using the chemistry virtual laboratory. In the study, 90 students from three different ninth-grade classes were randomly divided into control and

experimental groups. The control group was taught practical using real chemistry laboratory while the experimental group was taught the same concept using virtual chemistry laboratory. Both groups received the instruments, that is the Laboratory Equipment test (LET), Chemical Changes Achievement Test (CCAT), and Unstructured Observations. The collected data were analyzed, and the results show that, there is no significant difference in the achievement of control and experiment groups and that students in virtual chemistry laboratory could recognize laboratory equipment as those in the real chemistry laboratory. The findings indicated virtual chemistry laboratory software to be as effective as the real laboratory.

Additionally, Ratamun and Osman [25] compared the effectiveness of physical chemistry laboratory and that of virtual chemistry laboratory in the mastery of science processes and skills in chemistry experiment among science student. The instrument used was the Science Processes and Skills Mastery Test (SPST). The research design adopted was quasi-experimental with a nonequivalent control group where a total of 147 participants of the research were chosen using a purposive sampling method at Malaysian 4th-grade science students. Two-way ANCOVA analysis revealed the performance of those taught in physical chemistry to be higher but of no significant difference indicating virtual chemistry laboratory to be effective also in science processes and skill mastery in chemical experiments involving confirmatory tests for cations and anions. Also, the findings show no gender influence in learning chemistry through the virtual chemistry laboratory. Nevertheless, many studies carried out on the effectiveness of virtual chemistry laboratory in learning chemistry practical had proved similar findings [14]; [26]; and [27].

In the case of distance learning education, students are mostly either away from their school or the tightly scheduled that prevent them from enrolling in full-time regular programs, virtual laboratory proved to be significant for them. Nathaniel [28] investigated the effectiveness of a virtual chemistry laboratory for distance learning chemistry students. The study was designed to compare the familiarity of students with laboratory identification of laboratory apparatus using virtual chemistry laboratory and real chemistry laboratory. Data obtained using a questionnaire and interview suggested the majority of students who used virtual chemistry laboratory found it valuable environment for learning about component of a chemistry laboratory and recommended it for use. Those who worked with real chemistry laboratory were found to have an average score higher than those who worked with virtual chemistry laboratory even though there is no significant difference between the two groups at 0.05 levels of alpha. They concluded that the virtual chemistry laboratory can serve as an effective tool for getting familiar with the laboratory setup and identifying its facilities especially for distant learning chemistry students or any other category of students that lacks access to the standard real chemistry laboratory.

In the Nigerian context, the researchers were able to access one study regarding virtual chemistry laboratory. Nathaniel [29] carried out a study that examined the effect of combined virtual and real chemistry laboratories on the academic achievement of chemistry students of science secondary schools in Nigeria in practical chemistry. The instrument used was Chemistry Practical Achievement. Students were asked to carry out volumetric analysis and respond to questions. The findings revealed that students who worked with both virtual and real chemistry laboratories performed significantly better than those who worked with only real chemistry laboratory. Hence using virtual chemistry laboratory as a supplement to real chemistry laboratory in conducting chemistry practical is more profitable in enhancing students' understanding and achievement. Therefore, the virtual chemistry laboratory could be used as a supplement and support in schools with and those without real chemistry laboratory respectively.

From the literature, it can be deduced that supporting the existing laboratories in Nigerian secondary schools with virtual chemistry laboratories, would overcome the problems of the inadequacy of facilities, overcrowding in laboratories, facilities breakage by students and safety challenges in the case of dangerous experiments.

III. FEATURES/BENEFITS OF VIRTUAL CHEMISTRY LABORATORY

Features of the virtual chemistry laboratory make it efficient and significant in conducting chemistry practical. Some of these benefits include; flexibility, low-cost of subscription and maintenance, multiple access, change in the system of configuration, instant feedback and top-notch equipment.

A. Flexibility

The virtual chemistry laboratory is a flexible learning environment that allows learners to carry out experimental activities using real illusion and not minding the insufficiency of facilities and reagents to be used. Both teachers and students could conduct their experiments at their convenient time and place, unlike the real laboratory where experiment must be conducted within the stipulated time by the school management or risk interruption and overlapping of one activity into the other [30]. According to Su [23] and, Mustafa and Albert [5], students can use virtual chemistry laboratory at their convenient time to study and practice various practical lesson which supports students' learning process and mastery in skills and subject matter.

B. Low Cost of Subscription and Maintenance

Although there are some charges for a subscription for some virtual laboratories, the charges can be shared among schools that collaborated to subscribe [31]. The collaboration would lower the cost of subscription and maintenance. All the collaborators can access the laboratory and use the facilities to their satisfaction. By this logic, both subscription and maintenance of virtual chemistry laboratory combined would not be up to that of purchase and maintenance of real laboratory where some consumable and reagents must be purchased either daily or regularly.

C. Change in System of Configuration

In the case of real laboratory, there are parameters with many machine that cannot be tempered or changed to the required unit and fraction, being that the manufacturer did not provide room for that, while in the virtual laboratories similar machines and parameters could be changed to sooth the unit and functions needed for the experiment [32].

D. Multiple Access

Many students can access the same experiment in the virtual chemistry laboratory from a different location at the same time. It gives room for students to re-experiment any experiment they carried out at any time and anywhere. A student is only required to log in using his username and password and access the environment. There is also a virtual chemistry laboratory environment such as Micro-Telk's Virtual Training Lab that offers free access to a practical lesson for a student who wants to reinforce or master what he/she was taught in the class or during school hours [33].

E. Top-notch Equipment

In chemistry and any other experiment, recent and standard equipment always yield better and more reliable results, as such recent and high-quality chemistry laboratory equipment are expected to be utilized in carrying out practical to avoid chances of error and reporting the wrong result. Virtual chemistry laboratories are established and maintained by high profile and capable companies that are up to date and committed to supplying the most recent qualitative laboratory equipment [32]. This recent equipment is very expensive that many schools cannot afford to purchase, to furnish their real laboratory.

F. Instant Feedback

Virtual chemistry laboratory enables the learner to carry out an experiment and get the result instantly. This informs the learner of his strength and weakness for proper adjustment and can decide to re-conduct the experiment for better improvement [23]. Practice questions could also be formulated for learners to test their understanding and practical skills through instant feedback.

G. Students' Interest and Engagement

Students of today feel excited and appreciate working with technology due to its penetration into every nook and cranny of human endeavour. Instead of playing unnecessary games and chats they could use their mobile phones and play interactive games within the virtual chemistry laboratory which make them feel interested, motivated and engaged. According to Paula [34], the virtual chemistry laboratory is a technology-based laboratory with quite interesting and amazing features, facilities and interactive games that make students feel highly motivated and engaged in learning, showing the willingness and temptation to discuss the experience they gained through the use of virtual laboratory in conducting experiments.

IV. AVAILABLE SITES FOR VIRTUAL CHEMISTRY LABORATORY

There are a lot of sites and applications that provides customized and ready-made practical lessons in most of the chemistry topics. Some apps also have features and facilities that give room for chemistry teachers/laboratory technicians to create a learning environment that soothes his/her lesson's plans and objectives.

A. ChemCollective

It is a collection of scenario-based learning activities, tutorials. Teachers can use the content for many activities both at home and in the class for individuals or group. Students can also learn chemistry concepts with the use of ChemCollective through virtual laboratory simulations and tutorials. It is a site created and organized at Carnegie Mellon by a group of faculty and staff who are interested in using, assessing, and creating engaging online activities for chemistry education. It is a National Science Digital Library based project that supports a community of instructors who are interested to create and improve scenario-based learning chemistry instruction with engaging and interactive online activities. The site for this project is http://chemcollective.org/vlab_download/.

Fig. 1: Inner view of a virtual Chemistry Laboratory (Adapted from http://chemcollective.org/vlab_download/)

Fig. 2: Virtual Chemistry Laboratory Set-up for Solution Preparation (Adapted from http://chemcollective.org)

B. Virtlab

This is a free web-based simulation designed laboratory for a student to conduct practical chemistry. It comprises a series of hands-on experiments that demonstrate how to use the virtual chemistry laboratory to carry out the chemical experiment. It further provides room for users to design and develop their own virtual laboratory environment. The developers of this learning environment were among the first educators all over the world that pioneered the integration of science education in a personal computer [35]. This site can be reached through http://www.virtlab.com/.

C. Labster's Virtual Labs

In the labster virtual chemistry laboratory, students have access to practical chemistry lessons for learning in an effective and interesting way. It presents students with true-to-life chemical laboratory experience at a fraction of the cost of a real chemistry laboratory. Teachers can supplement their practical lessons with a labster virtual laboratory in order to prepare their students, chemistry practical with zero risks of danger. It is a real three-dimensional package with animations, that enable students to explore real-life concepts at the molecular level [36]. The site address for labster is https://blog.labster.com/

Fig. 3: Inner View of Labster Virtual Laboratory (adopted from https://blog.labster.com/)

D. Second Life

This is an application available in the google store and play store that can be used to design and enrich students in fun learning and interactive 3D environments. It allows the user to collaborate, teach, and create together an interactive learning environment using voice, image and text. Hundreds of educators are joined together around the world by this forum. Chemistry educators can use this application and design a virtual chemistry laboratory for their students.

V. CONCLUSION

The paper presented virtual laboratory chemistry as an alternative strategy for conducting chemistry practical, particularly in schools that lack standard real chemistry laboratory or due to financial constraint may not afford to establish and maintain a standard chemistry laboratory for experimentation of various concepts. Features of virtual chemistry laboratory make it efficient and significant in conducting chemistry practical as such, it could be used as a supplement and support in schools with and those without real chemistry laboratory respectively. It was, therefore, suggested that science secondary school should integrate virtual chemistry laboratories in chemistry practical. Also, science secondary schools in Nigeria without a functioning real chemistry laboratory can even support it with the virtual ones.

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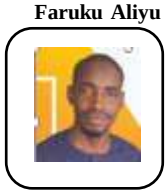

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