EFFECTS OF VIRTUAL LABORATORY ON THE ACHIEVEMENT AND RETENTION OF BIOLOGY STUDENTS IN SENIOR SECONDARY SCHOOLS IN MINNA, NIGER STATE

BY

PETER, Faith Odafe

2015/1/55682BT

DEPARTMENT OF EDUCATIONAL TECHNOLOGY

SCHOOL OF SCIENCE AND TECHNOLOGY EDUCATION

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

AUGUST, 2021.

EFFECTS OF VIRTUAL LABORATORY ON THE ACHIEVEMENT AND RETENTION OF BIOLOGY STUDENTS IN SENIOR SECONDARY SCHOOLS IN MINNA, NIGER STATE

BY

PETER, Faith Odafe

2015/1/55682BT

PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF EDUCATIONAL TECHNOLOGY, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF BACHELOR OF TECHNOLOGY (B.TECH) IN EDUCATIONAL TECHNOLOGY FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

NIGER STATE

AUGUST, 2021.

ABSTRACT

This study covers the effects of virtual laboratory on the achievement and retention of Biology students in senior secondary schools. This study adopted the quasi-experimental design. Specifically, the pretest, post-test, non-equivalent control group design was used. The population use for this study comprises of Biology students in Minna Metropolis, Niger state with a total population of 2170 students while the target population comprises second-year secondary school (SSII) Biology students in Mina Metropolis, Niger State. Purposive and simple random sampling techniques were used to select two schools. The sample size consists of 50 students from the two schools. Findings from this study revealed that students taught using Virtual laboratory had higher mean achievement score than those taught without virtual laboratory. Finding revealed that there was no significant difference between the mean achievement scores of male and female Biology students taught using Virtual laboratory package. Based on the finding of the study, it was recommended that there should be adequate reinforcement to hardworking and dedicated teachers through prize awards as a means of appreciation. Government, school administrators should show support and dedication to encourage creativity shown by co-science teachers by providing teaching materials which will promote science and technology in Nigeria.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to The Study

Rapid technical advances and innovations, such as computers and the Internet, provide new possibilities for teaching and learning (Raja & Nagasubramani, 2018). As we progress into the Information Age, technical developments are transforming the operation and activity of institutions. Education has also been influenced by this shift. In an attempt to educate students to be productive participants in society, it is critical that teachers adapt to the demands that these developments present. Technological and educational advancements are sure to transform the way certain schools look and work (Summak *et al*, 2010).

Virtual Reality can be described as an advanced type of human-computer interaction that helps the user to communicate with and immerse themselves in a computer-generated world in a naturalistic manner. In much the same way as aircraft simulator training and piloting skills, computer-generated virtual environments (VEs) may be programmed to assess and rehabilitate cognitive and functional capacities, and to include control capabilities (Manca & Nazir, 2012).

Virtual Reality can be experienced via the senses of light, sound, and touch. The tremendous advancement of computing and communications technologies has contributed to the advent of creative ways of developing diverse types of interactive worlds, including teaching and learning environments. Today, many educational software use simulations to render events that cannot be replicated in laboratories (Oser, 2013). Tatli and Ayas (2013) argued that experiments, usually conducted in physical laboratories, can now be done on a computer.

When performing an experiment in a virtual environment, students actively engage in the whole process, work with others to complete experiments.

Virtual Reality computing systems are known to be the most suitable simulation applications because they can enhance user perception through images, sound and 3D (Three Dimensional) world immersion. The use of computers in teaching and studying science, in particular biology, has many specific characteristics. For example, they can be used to support students at the level of the particles, to perform harmful Biology practical in a virtual laboratory, to study unseen parts of the human body in a virtual 3D environment, and so on. The use of laboratories is of significant importance in science teaching, teaching through the laboratories is one of the basic characteristics of the teaching of science (Al-Hassan, 2016). Virtual laboratory software is a supportive tool in real labs or as an alternative lab where there is not an available physical lab. or conditions of the physical lab are insufficient (Tatli & Ayas, 2010). Similarly, Larbi-Apau (2020) added that the virtual laboratory is an immersive platform for the creation and conduct of simulated experiments. This entails performing experiments with domain-dependent simulation programmes. In particular, virtual reality technologies can be applied to construct a virtual laboratory to replicate procedures and actions in actual laboratories. Kolil *et al*. (2020) noted that using the 3D Interactive Laboratory, students were able to deepen their experience and knowledge with both experiments and tools.

Based on research, introducing students to Virtual laboratory and helping them better understand them through successful hands-on learning increases their experimental self-efficacy substantially (Ramadhan & Irwanto, 2017). They observed that virtual Laboratory is able to increase students' learning motivation on biology concepts, the students' learning

motivation on dissection is categorized high with an average score of 73.28%. Virtual laboratories replicate actual laboratory environments and processes and are characterized as learning environments in which students translate their theoretical knowledge into realistic knowledge by performing experiments (Maulidah & Prima, 2018).

Virtual laboratories provide students with practical virtual experience and address essential ideas, values and processes. Through the use of interactive laboratories, students have the ability to replicate some erroneous experiment or to deepen their expected experience. Performing experiments using a virtual environment is more effective than performing experiments in real laboratories, virtual laboratory enables learners to repeat the practical several times without hesitation, or to zoom in and out, and to watch the experimental process in slow motion (Gambari, *et al*., 2018). For this purpose, students should have virtual laboratories built also on home computers to enable them to conduct basic experiments outside the school laboratory to increase comprehension. Simulation can not only motivate students, but offers accessible means for students to gain an intuitive understanding of abstract chemical phenomena.

In Nigeria, at secondary school level especially for the science students; Biology is considered as one of the core science subjects to be taught at that particular level and tertiary levels. Biology is a core science subject taught in the secondary school as prerequisite course for admission into tertiary institutions to study natural science courses. Qualitative functional biological knowledge is practical and useful but the Nigerian formal education has not provided school learners with functional education (Ayodele, 2018). Gongden *et al.* (2011) noted that Nigeria is a developing nation and the importance of biology for such a nation cannot be over emphasized. Chikendu and Okoli (2020) defined Biology as a subject in the

life sciences. Biology is a branch of science that deals with living organisms and their vital processes (Rogers, 2021). Hasssan and Salihu (2019) described biology as one of the most important bedrock for all scientific subjects such as physics, chemistry, genetics, geology, medicine, pharmaceutical research, among others.

Learning Biology involves visual comprehension, and it is obvious that certain Biological concepts can be well understood through visual representation (Çimer, 2012). In recent times there has been a call to shift from teacher-centered learning activities to student centered activities that make the students more responsible for their own learning as endorsed by activity theory (Schreurs & Dumbraveanu, 2014). Students without adequate knowledge of fundamental Biology concept can find it difficult to comprehend science concepts and science phenomena.

Mastura (2019) defined academic achievement as the attained level at which the students are functioning in school task as means used by grade marks or grade earned. Tuysuz (2010) revealed that that the use of virtual lab increased students' achievement levels. Similarly, Tatli and Ayas (2013) concluded that virtual laboratory software is effective as the real laboratory, both in terms of student achievement in the unit and students' ability to recognize laboratory equipment.

Ugwanyi *et al*. (2020) opined that achievement is a function of retention, which implies that students' ability to remember have the tendency of improving that student achievement. To this end, virtual laboratory could improve retention. Retention in this study is an act possessed by a Biology student in remembering a task or material learnt. In some review of empirical studies on retention in science concepts, Suleman (2020) found out that the students

taught with computer assisted instruction (CAI) retained learning for longer time than the students taught using the traditional method. Similarly, Nweke (2019) reported that students taught computer studies using computer-assisted instructional package improved the achievement and retention of students. Also, they did not find any gender difference in achievement and retention of students taught in computer assisted instructional package computer science.

Gender issues have been linked with performance of students in academic tasks in several studies but without any definite conclusion. Some studies revealed that male students performed better than the female in science courses. For instance, Aina and Akintunde (2013) found that male students performed better than female in interactive physics, while Abungu *et al*. (2014) found that girls performed better than boys using science process skills method of teaching. However, Adigun (2015), Dania (2014) and Glory and Sopuruchi (2017) reported that gender had no influence on academic performance of students.

This research is geared towards effects of virtual lab on the achievement and retention of Biology students in senior secondary schools in Minna, metropolis, Niger state.

1.2 Statement of the Research Problem

The search for innovative teaching strategies is borne out of the fact that there is a general worry about the poor quality of Nigeria students' performance (Yaki *et al*. 2015). The traditional method of teaching is very popular and is widely used by Science teachers even in practical lessons to convey large volumes of scientific information to senior secondary school students in a bid to prepare them for Senior Secondary School Certificate Examination. Hence the need to seek innovative instructional strategies that could improve

performance and enhance learners' acquisition of science process skills especially in practical lesson. Angwal *et al*. (2020) noted that in the West African Examination Council (WAEC) it was reported among other things that candidates were unable to make logical inferences from experimental results and inability to relate structures of specimen to their function. Hence, the WAEC Chief examiner's recommended that "Biology teachers should be sponsored and encouraged to join professional association like Science Teachers Association of Nigeria to enables them keep abreast of new teaching techniques and development in their subjects." (Yaki *et al*., 2020). This clearly shows that secondary school teachers still use traditional teaching technique despite the aforementioned benefit of the use technology in teaching. Also, the reason for not teaching students practical concepts can be attributed to the unavailability and accessibility to laboratory (Pareek, 2019). Hence, the study is geared towards assessing the effects of virtual lab on the achievement and retention of biology students in senior secondary schools in Minna, metropolis, Niger state

1.3 Aim and Objectives of the Study

This study aims to assess effects of virtual lab on the achievement and retention of biology students in senior secondary schools in Minna, metropolis, Niger state. Specifically, the study will achieve the following objectives:

1. Determine the mean achievement score of Biology students taught using virtual laboratory and those taught without virtual laboratory
2. Determine the mean retention score of Biology students taught using virtual laboratory and those taught without virtual laboratory

3. Determine male and female Biology students mean achievement score taught using virtual laboratory
4. Determine male and female Biology students mean retention score taught using virtual laboratory.

1.4 Research Questions

The following research question were formulated to guide this study:

1. What is the mean achievement score of Biology students taught using virtual laboratory and those taught without virtual laboratory?
2. What is the mean retention score of Biology students taught using virtual laboratory and those taught without virtual laboratory?
3. Is there any difference between male and female Biology students mean achievement score taught using virtual laboratory?
4. Is there any difference between male and female Biology students mean retention score taught using virtual laboratory?

1.5 Research Hypotheses

The following null hypotheses are formulated to guide this study

$H0_1$: There is no significant difference between the mean achievement score of Biology students taught using virtual laboratory and those taught without virtual laboratory.

$H0_2$: There is no significant difference in the mean retention score of Biology students taught using virtual laboratory and those taught without virtual laboratory.

$H0_3$: There is no significant gender difference in the mean achievement score of Biology students taught using virtual laboratory

$H0_4$: There is no significant gender difference in the mean retention score of Biology students taught using virtual laboratory

1.6 Significance of The Study

These findings will be of immense benefit to classroom students, teachers, school authorities, curriculum developers, researchers, and the Ministry of Education.

The findings of this study will help the students to be effective and proficient in the mastery of the subject matter since technology is beneficial and brings innovation and development to the teaching and learning process. It will also help them discover their full potentials.

This study will help the teacher on how to improvise and also guide the pupils on better use of technology in the classroom. These findings will also help the teacher to be resourceful and to develop problem solving skills in regards to technological use.

The findings will help to create awareness and enlighten among the school authorities of the importance of technology and its effectiveness in the classroom for teaching and learning. The findings of this study will also help the curriculum developers on the vitality of technology integration and its effectiveness in teaching and learning in secondary schools and take cognizant when planning curricular.

This research will also provide information and add up to the body of already existing literature for further studies for other researchers.

Furthermore, findings from this study will be significant to the ministry of education of all level in Nigeria, because it will provide the vital information to the government about the state of education in Nigeria. The assessment of technological integration will serve as a basis for the improvement of technological use in the country as a whole.

1.7 Scope of The Study

This study assessed the effects of virtual lab on the achievement and retention of biology students in senior secondary schools in Minna, metropolis, Niger state. This study will be carried out at Ideal Royal School due to the availability of ICT technologies and computers to install the virtual lab. This study was be carried out among SSII Biology students, the students will be taught Rabbit dissection. This study lasted for six (6) weeks.

1.8 Operational Definition of Terms

Virtual Reality: is an advanced type of human-computer interaction that helps the user to communicate with and immerse themselves in a computer-generated world in a naturalistic manner

Virtual laboratory: a simulation of the real world for the purpose of discovery learning

Biology: Biology is a branch of science that deals with living organisms and their vital processes.

Achievement: is the attained level at which the students are functioning in school task as means used by grade marks or grade earned

Retention: act possessed by a Biology student in remembering a task or material learnt

CHAPTER TWO

2.0 LITERATURE REVIEW

The major areas reviewed under this project work have been classified under; conceptual framework, Theoretical framework and Empirical studies

2.1 Conceptual Framework

2.1.1 Concept of Biology

Science and technology play a vital role in the development of any nation. They are the predictors of success and development of any nation's economy. Biology occupies a central position among all science subjects. Biology a life science stands at the center of science and technology. As a life science subject, it has contributed greatly towards improving the quality of human life by providing drugs for curing and preventing human diseases. In addition, the course is also a gateway to noble professions like Medicine, Pharmacy, Dentistry, Nursing, Agriculture, among others (Ityokyaa & Adejoh, 2014). Research evidences have proved that biology's contribution to quality of life and nation building is enormous in all aspects of human endeavour (Awosika, 2008). Probably that is why the developed nations recognized the relevance of biology in their national economy. It was based on this fact that the Federal Republic of Nigeria through her National Policy on Education made biology a compulsory science subject at secondary school level (FRN, 2013).

Biology is a science concerned with the study of life and living organisms, including their structure, function, growth, evolution, distribution, and taxonomy (Mouhamad, 2018). The word biology is derived from Greek origin: bios means life, and logos means science or study (Biology Online, 2021). Therefore, Biology is the science of Living Things That is why

Biology is sometimes known as Life Science. Biology is a highly relevant science to our lives. We human beings are biological organisms. We learn biology to know how the human body is made, how it works, and what organs are in the body (Mouhamad, 2018). We must study biology because we must learn about life in our environment. Some important reasons for studying biology have to do with understanding how cells and organisms work. Biology involves the study of life and how plants, humans and animals work. You will better know how your body works. Biology touches your life in many ways every day. Biology can tell us about the physical makeup of our bodies, which enables us to produce cures and treatments for many diseases. Biology can also tell us about plants of major importance and what plants can help our body systems to be healthy. Biology also helps us know the different body systems of different animals and also ourselves. Also biology can help us know more about the organisms in our bodies. Biology can also tell us why animals act the way they do, also why humans act the way we do

2.1.2 Biology Curriculum in Nigeria

Learning cannot take place without a planned of programme of activities; and the document that contain the totality of activities that take place in schools is termed curriculum (Akintola, 2018). Abimbola and Mustapha (2003) defined Curriculum as an educational programme of what goes on in the school and outside the school. Thus, science curriculum can be operationally defined as carefully planned and intended learning outcomes. In Nigeria, the sciences are taught in school subjects as Biology, Chemistry and Physics. Reiterating the importance of biology, Umana (2018) opined that no nation can be scientifically and technologically developed without adequate level of biology education. An alternative

learning environment, called a virtual laboratory, can help to make this crucial educational application available to students (Ramadhan & Irwanto, 2017).

Ajaja (2007) stated the objectives of teaching science to include obtaining the knowledge of science academic discipline, acquiring scientific methods and skills, acquiring clear knowledge and convincing explanation on societal issues through scientific literacy and societal goals, making provisions for personal needs and creation of career awareness

The objectives of teaching science identified by Ajala (2007) are meant to make relevant knowledge in science subject available to an individual. Such subjects in senior secondary schools include Biology, Physics, Chemistry and Mathematics. Also, scientific skills of observation, identification, classification, recording, experimenting, measurement, making inference etc. will be developed by an individual. Furthermore, explanations to some societal issues that could only be answered through scientific knowledge will be provided. Among the objectives of science teaching is to cater for the personal needs of an individual. The invention of solar power, Television, Radio, mobile phones etc. were to provide for personal needs of an individual among others. Various careers in medicine, engineering, agriculture, communication are provided through science teaching.

Biology is the branch of science that involves the study of life. Biology is such a broad field, covering the minute working of chemical inside our cells, to broad scale concept of ecosystem and global climate change. Biology covers all the life processes such as movement, respiration, nutrition, irritability, growth, excretion and reproduction. The life processes are characteristics of all living things either plant or animal regardless of races and geographical distributions.

The National Policy on Education (FRN, 2013) explained that the learning of Biology will provide the students with suitable laboratory and field skills in biology, meaningful and relevant knowledge in Biology, scientific knowledge that is applicable, in health, agriculture, personal and community daily life matters and development of functional scientific attitudes.

To make objectives of teaching and learning of Biology achievable, emphasize should be placed on field studies, guided discovery, laboratory techniques and skills along with conceptual thinking in the curriculum. In pursuance of the stated objectives, the (2009) edition of the Biology curriculum (NERDC, 2009) has organization of; life, work, environment and continuity of life as its themes.

2.1.3 Concept of Information and Communication Technology

Information and Communications Technology (ICT) is an extended term for information technology (IT) which stresses the role of unified communications and the integration of telecommunications (wired and wireless signals), computers as well as necessary enterprise software, middleware, storage, and audio-visual systems, which enable users to access, store, transmit, and manipulate information (Aibara, 2017). However, ICT has no universal definition, as the concepts, methods and applications involved in ICT are constantly evolving on an almost daily basis (Elisha, 2006). The broadness of ICT covers any product that will store, retrieve, manipulate, transmit or receive information electronically in a digital form. e.g. personal computers, digital television, email, robots (Aibara, 2017).

Pratt (2019) observed that ICT is the fusion of infrastructure and components that enable modern computing. Fu (2013) noted that ICT provides practical experience and reflective engagement on critical issues related to Information and Communication Technologies in a

workshop mode through presentations and seminars around selected readings, engaging student to understand the role of ICT in education in relation to various policies and curriculum frameworks on ICT and in diverse socio-economic contexts. To assure that it provides a rich learning experience for student through various ICT tools to enable them. Information Technology in Education, is effective in the continuous developments in ICT on education (Ghavifekr, 2015). The pace of change brought about by new technologies has had a significant effect on the way people live, work, and play worldwide (Allen, 2019). New and emerging technologies challenge the traditional process of teaching and learning, and the way education is managed.

ICT is having a major impact across all curriculum areas. Easy worldwide communication provides instant access to a vast array of data, challenging assimilation and assessment skills. Rapid communication, plus increased access to IT in the home, at work, and in educational establishments, could mean that learning becomes a truly lifelong activity (Negi, Negi & Pandey, 2011). ICT continues to evolve very quickly and has now become a fundamental tool in many aspects of everyday life, both at home and in the workplace. Because of this, it is essential that all pupils gain the confidence and ability within this subject to prepare them for the challenge of a rapidly developing and changing technological world.

2.1.4 Information and Communication Technology in Education

Schools use a diverse set of ICT tools to communicate, create, disseminate, store, and manage information (UNESCO, 2021). Integration of ICT in classroom is getting more important as it help student in enhancing their collaborative learning skills as well as developing transversal skills that stimulates social skills, problem solving, self-reliance, responsibility

and the capacity for reflection and initiative (Ghavifekr & Rosdy, 2015). In some contexts, ICT has also become integral to the teaching-learning interaction, through such approaches as replacing chalkboards with interactive digital whiteboards, using students' own smartphones or other devices for learning during class time, and the "flipped classroom" model where students watch lectures at home on the computer and use classroom time for more interactive exercises (Vidhate, 2019). When teachers are digitally literate and trained to use ICT, these approaches can lead to higher order thinking skills, provide creative and individualized options for students to express their understandings, and leave students better prepared to deal with ongoing technological change in society and the workplace (Vidhate, 2019). ICT issues planners must consider include: considering the total cost-benefit equation, supplying and maintaining the requisite infrastructure, and ensuring investments are matched with teacher support and other policies aimed at effective ICT use (UNESCO, 2021).

2.1.5 The laboratory in Science Education

In the United States, the laboratory has been a central component of science education for over 200 years (Lunetta *et al*., 2007). For example, in 1893 the Committee of Ten strongly advocated for the use of the science laboratory by recommending "double periods for laboratory instruction, Saturday morning laboratory exercises, and one afternoon per week to be set aside for out-of-door instruction in geography, botany, zoology, and geology" (DeBoer, 1991). Many educators argue that the science laboratory is where students make meaningful connections to the science content taught in the classroom and encourages scientific habits of mind (Lunetta *et al*., 2007). This is evident in the prominent role of science laboratory exercises and activities in science education benchmarks and standards (National Research Council, 2007; NGSS Lead States, 2013).

However, not all educators agree that all students in all science courses should be required to engage in laboratory activities (Jenkins, 2007). Moreover, research results have not shown conclusive evidence of positive impacts of science laboratory exercises on student learning, but they may influence student attitudes and assist in the development of collaboration and communication skills (Hofstein & Lunetta, 2003). While the nature of this debate over the purpose and benefits of science laboratory instruction has not changed, technological advances have made additions to the landscape of possible laboratory environments. The science laboratory moved into the realm of distance education with the advent of at home science kits where students are mailed or purchase simple laboratory materials to complete activities in their in own home (Hallyburton & Lunsford, 2013; Johnson, 2002).

Today, advances in technology have allowed computer simulations and virtual laboratories to rapidly become a regular component of the landscape of science laboratories. Virtual laboratory is a learning environment in which students convert their theoretical knowledge into practical knowledge by conducting experiments (Woodfield, 2005). Virtual laboratories simulate a real laboratory environment and processes. They provide students with meaningful virtual experiences and present important concepts, principles, and processes. By means of virtual laboratories, students have the opportunity of repeating any incorrect experiment or to deepen the intended experiences. Moreover, the interactive nature of such teaching methods offers a clear and enjoyable learning environment (Jeschke *et al*., 2010).

A virtual laboratory may sometimes be a preferable alternative, or simply a supportive learning environment, to real laboratories. It provides students with opportunities such as enriching their learning experiences; conducting experiments as if they were in real laboratories; and improving their experiment related skills such as manipulating materials

and equipment, collecting data, completing experiment process in an interactive way (with boundless supplies), and preparing experiment reports (Subramanian & Marsic, 2001). Researchers have determined that instructions carried out with virtual laboratories significantly increase student achievement levels (Dalgarno, Bishop, Adlong, & Bedgood, 2009; Yu, Brown, & Billet, 2005 & Tatli, & Ayas, 2013). Virtual environments let students observe the process in more detail, compared to board and chalk activities of the traditional classroom or partially completed experiments of the real laboratory environment. In addition, virtual environments foster attention and motivation towards the course by supporting a discussion platform among partners, peers, and among students and teacher (Dobson, 2009; Lawrence, 2011).

2.1.6 Concept of Virtual Reality

Virtual Reality (VR) concept is a term that we often hear and familiar with nowadays by the development of computer technologies. Today, virtual reality technology is used in many fields such as vehicle and flight simulations, entertainment, product design, architectural design and interior arrangements, education, medicine with an increasing efficiency (Peng, 2011). Virtual reality is not limited by defining any technological approach or hardware fiction. But it's seen that this concept is used to describe different environments and systems by different researchers. The VR terms is widely understood that it's a "non-immersive" computer simulation using 3D graphics and tools and providing interactive interaction (Oh *et al.*, 2004). Digital contents such as internet, graphics, multimedia, etc. that are experienced only by basic components of a computer is meant here. Non-immersive VR is experienced by modern computer and game console systems in general. Users can be directed in the 3D graphical environment (without real word occlusion) by means of a flat screen monitor or television in this format

and interact (Kılıç, 2016). Despite the fact that such systems are less immersive, they are basically characterized as a virtual environment. Virtual environments (VE) provide a system to the user, which can be accessed in a commercially widespread manner, allow interaction with dynamic, digital content by using traditional computer and game interface devices (keyboard, mouse, game pads, joystick, etc.) (Kılıç, 2016).

According to the definition of some researchers, the virtual reality technology is "immersive" systems including special I/O devices consisting of head mounted displays (HMD), gloves, haptic devices (haptic) or multiple displays and improves 3D experience of the user (Oh *et al*., 2004). As a result of these definitions, two approaches as "immersive" and "non-immersive" emerge for VR (Kılıç, 2016). A user in the real environment perceives only the physical world. As long as moving across from real environment to the virtuality, enrichment of the physical world with virtual objects or other components, i.e. "Augmented Reality" emerges (Kılıç, 2016). A person in the virtual environment experiences a synthetic environment created by computer as completely isolated from the physical world.

Virtual reality is the user entering a completely artificial environment (Bardi, 2019). The user cannot see the real world that surrounds him. What meant in this definition is immersive virtual reality systems? Virtual reality environment having immersive feature is interactive computer simulations that create a mentally drift perception or perception of being in the simulation environment and allow user to interact or move (Bohil *et al*, 2009). Basically, a virtual reality environment is the environment, where the observer enters in an artificial and three-dimensional world by leaving the real environment, interacts such as being, walking there, change locations and features of objects and as a result of these interactions, gets sensory reactions as in the real world (Kılıç, 2016). Virtual reality should include four basic

components: virtual environment, immersion, sensory feedback (as reaction against the user's movements) and interaction (Muhanna, 2015).

A virtual learning environment (VLE) in educational technology is a web-based platform for the digital aspects of courses of study, usually within educational institutions (Wikipedia, 2021). They present resources, activities, and interactions within a course structure and provide for the different stages of assessment. VLEs also usually report on participation; and have some level of integration with other institutional systems. For teachers and instructors who edit them, VLEs may have a fact role as authoring and design environments. VLEs have been adopted by almost all higher education institutions in the English-speaking world. Alphin (2014) noted that a virtual learning environment (VLE) is a computer-based synchronous and asynchronous higher education learning system that includes learning management systems,

2.1.7 Learning in a Virtual Environment

Reisoğlu *et al* (2017) observed that users of virtual environment are able to access virtual contents simultaneously, share information, receive multifaceted feedback (Cheng and Wang 2011), and conduct activities by interacting with objects and individuals from online connection points in different locations. The field of education has seen the use of digital virtual worlds for several years (Clifford, 2012), increased advances in capabilities of educational technology has resulted in massive use of multi-users virtual worlds: this has fed interests in educational application and the use of Virtual Learning Environments (VLEs). Besides, VLE has enabled educational world to sell their products online thus, public and private sector education view students as consumers (Nwabude *et al*, 2020).

Although, virtual learning has the potentials to offer good and distance education comparable to physical classroom situation in the developed environment (Murphy, 2020), some parts of the developing world appear to struggle in harnessing and accessing these potentials to meet the needs of e-learning subscribers in this turbo-charged digital race (Nwabude *et al*, 2020). Essentially, several frameworks and models have been adopted by stakeholders towards implementing eLearning through the use of computers, technologies and internet (Kılıç, 2016). Nwabude (2020) defined a virtual learning environment as a physical, intellectual, and psychological environment which facilitates learning through connectivity and community. Following this definition, the Joint Information Systems Committee (JISC) in July 2000, recommends that the term 'virtual learning environment' ('VLE') should also refer to 'the components in which learners and instructors participate in "online" interactions of various kinds, including distance on-line learning' (JISC, 2001).

With these definitions and additions in the minds of computer and technology scientists, software developers, and education managers, comes the realisation that a VLE indeed describes a particular toolset designed for and with instructors and learners in mind (Nwabude *et al*, 2020). Virtual Learning Environment (VLE) offers the ability to schedule a range of learning activities and make tools available rather than just managing contents (Schlater, 2009). In other words, a VLE provides necessary tools which might enhance student's learning experience and also provides flexible environments where students might choose to learn at a time suitable.

Broadening our knowledge of a VLE further is the concept as a one stop shop from the European Schoolnet (EUN, 2003) which argues that the evolution of VLE and its success is dependent upon the integration of such components as course outlines, email, conference

tools, threaded discussions, home pages, assignments, assessments, feedback tools, multimedia resources, Web publishing, chat and diagnostic tools, file upload with tools for building knowledge and linking administrative information. Underlying all these definitions and concepts are two central meaning: first, virtual learning environment supports social constructivist approach to teaching and learning Konrad, 2003 and Oliver & Harrington, 2003).

Second, it "provides learners with all the facilities and learning opportunities that they experience in a face-to-face teaching situation even with added advantages of flexibility of access to digital discussion, support, resources, and assessment" (Nwabude, 2020). Thus, implies that a VLE platform has the capability to increase learners' tendency to learn, to multitask and to develop social autonomy through added tools and flexible learning environment. It also, provides learner the extended programme beyond the four walls of the classroom anywhere, anytime as long as learner has log-in access to virtual classroom through the Institution's portal. Although, VLE cannot work on its own except there is a working internet connected to a computer system and both lecturers and students possess the e-skills and knowledge to access, use and interact with it.

2.1.8 The Prospects of Virtual Laboratories

Consequently, Africa and many of the third world countries have, to date, continued to lag behind their first world counterparts in terms of scientific activity and quality of life (Pearson & Kudzai, 2015). Advancements in the information and communication technology has opened up real opportunities for developing nations to narrow the gap between them and the developed nations. Of particular interest to this study is to evaluate the potential use of virtual

laboratories to augment or replace traditional physical laboratories in the training of scientists in Africa.

The use of virtual laboratories generally occurs because not all practicum can be carried out through experimental activities in real laboratories (Zaturrahmi *et al*., 2020). Theories or concepts that are abstract and difficult to explain using equipment in real laboratories, but still require real observations, are simulated using a system. A virtual laboratory is a system that can be used to support a conventional practicum system, so that the use of this virtual laboratory can provide opportunities for students to do practicum via computer, and experiments are possible to do anywhere (Bima, 2021). The use of a virtual laboratory can overcome several problems related to inadequate laboratory equipment and make a positive contribution in order to achieve learning purposes, especially for abstract concepts. Virtual labs provide virtual practicum that is most often used in learning (Lesthari, 2020). Based on the results of previous research, it is known that virtual simulation can help students to understand concepts, receive feedback, and provide an interactive, constructivist approach, and train students to think critically and creatively (Zaturrahmi *et al*., 2020). The advantages of using a virtual laboratory according to researchers from Labshare are:

(1) Increase access to laboratories,

(2) Reduce laboratory management and maintenance costs by up to 50%,

(3) Improve the quality of learning to support better learning,

(4) Encourage the exchange of knowledge, expertise and experience,

(5) Reducing laboratory equipment supplier costs.

With this virtual laboratory, it helps teachers to keep abreast of technological developments, especially to streamline learning during (and after) the Covid-19 pandemic. Covid-19 pandemic demands creativity and innovation from teachers to find ways to deliver effective learning topics. It cannot be denied that Covid-19 pandemic requires students to maximize 21st century skills, including: communicative, collaborative, critical thinking, creative and innovative (Zaturrahmi *et al*., 2020.

2.1.9 Virtual Labs in Enhancing Academic Performance

Radhamani *et al.* (2014) suggest improved performance in students using virtual labs. Usage analysis and surveys indicated that biotechnology virtual labs are significant elements in adaptive learning process in blended classroom environment. Virtual labs offer diverse analysis of a concept through different components such as a close emulation of a real laboratory 'experience' through animations, which in turn serves diagrammatic understanding of a concept or an experiment in an emphasized mode (Radhamani *et al.,* 2014). By simulating the key steps of an experiment, students may experience an alternative hands-on method of proceeding with the steps thereby promoting interaction with the laboratory scenario. This includes ways to reduce recurrence of mistakes as it cautions the user about the common errors one commits while handling equipment or while performing the experiment by resetting the experimental scene (Miyamoto, 2019). In current education prospect, computer-aided technologies provide special advantages for designing innovative biology course materials and developing highly interactive student-teacher relationship (Ghavifekr & Rosdy, 2015).

Modern web-based educational systems are distinct from the traditional educational models. Adapting to the web based educational systems requires certain qualities and different

learning pedagogies. With this change in the education trend, many educational and research institutions widely employed such innovative technologies for teaching and learning purposes (Serdyukov, 2017). This user-friendly, interactive and problem-oriented methodology of instruction helps users to realize the concepts in a more precise manner. Laboratory practices are fundamental in teaching and learning biology courses (Hofstein, 2017). There are lots of limitations to successfully carry out traditional labs mostly in developing countries (Auer *et al*, 2003). Time constrains, shortage of equipment and reagents, insufficient laboratory protocol, issues in personal safety, inadequate technical support etc. are the most common reasons of setting up a proper laboratory condition in most schools (Radhamani *et al*, 2014). Online labs may be an asset to many universities which confront economic issues in maintaining equipment and other necessary conditions that need to be met for a good laboratory practice (Diwakar *et al*., 2012).

Virtual labs are popularized as a visual tool that could add advantages to students and instructors towards reducing the laborious procedures in a more effective manner. Virtual labs offer diverse analysis through different components like user- interactive animations, simulations, remote-triggering of real laboratory equipment and haptic devices to employ productive online biotechnology laboratory (Diwakar *et al*, 2012). The actual feel and visualization of a real laboratory can be delivered through graphical animations to a greater extent. Animations provide a diagrammatic understanding of the concepts of an experiment in a better way that cannot be easily conveyed through text based or passive illustrations. Visualization techniques employed in virtual labs allow the student to freely experience the virtual world to strive to make learning science fun (Radhamani, 2014). In traditional lab system, users may face certain problems such as limited access to laboratory facilities,

equipment shortage, inadequate technical support, that may interfere with their curiosity for learning science. Virtual labs play a pivotal role in bridging the lack of lab facilities, and devising individual experience at a low cost and thus increase the chance of self-organized learning methods (Radhamani, 2014). This ultimately imparts analytical thinking skills among the learners. In this paper, we focus on the use of virtual biotechnology laboratory as a new pedagogy for promoting university student's learning experience. The study analyses the effect of virtual labs on student users thereby assessing the relationship between their cognitive and social presence in active learning.

2.2 Theoretical Framework

Two major theories that support the use of e-learning in classroom teaching and learning selected by the researcher for this study include: the technology acceptance model and the constructivism learning theory.

2.2.1 Technology Acceptance Model

The technology acceptance model (TAM) build the theoretical framework in this research. TAM states that the perceived ease of using a system and the perceived usefulness are the key components of technology acceptance. However, with increasing diversity of users as well as diversity of technical systems (visible vs. invisible, local vs. distributed) and using contexts (fun and entertainment, medical, office, mobility) the end-users are confronted with, more aspects might be relevant for understanding their acceptance patterns – beyond the ease of using a system and the perceived usefulness. The Technology Acceptance Model (TAM) is a theory of information systems that models how people come to adopt and use technology. The model stresses the importance of technological use for all individuals. It should be

recognized that there must be a behavioural intention (BI), which is a phenomenon that pulls people to use technology. This model's proponents observed that behavioural intention (BI) is determined by attitude (A), which is described as the overall perception of technology.

According to the model, as consumers are offered modern technologies to use, a variety of considerations affect their choice to use those technologies. Some of which include:

- Perceived usefulness (PU): this is seen as the length at which a person feels using a certain technology will improve his or her job efficiency. This means that students who will most likely use assistive technologies will understand how effective they are in completing a specific task.

• Perceived ease-of-use (PEOU)- this factor describes how easy or difficult it will be to use a certain piece of technology. If a technology is relatively simple to use, consumers may have a favorable outlook toward it. People using assistive technologies, for example, may often use their phones or applications whether they are simple to use and do not need a lot of effort. Other influences, such as social impact, age, and gender, may influence individuals' use of technology and their overall understanding of it.

2.4.2 Constructivism Learning Theory

Constructivism learning theory emphasizes the importance of learners developing their comprehension and skills from their own experiences. Constructivists conclude that information from the world interacts with ideas from the person, resulting in internalized constructs formed by learners. Constructivists have identified the assimilation and accommodation mechanisms that are critical in this relationship as people construct new insights from their interactions. They assume that as people assimilate new content, it becomes part of an already established body of information or expertise. Constructivism

seeks to understand how learners learn by drawing on prior experiences and constructing their own knowledge from those experiences. This suggests that constructivism promotes constructive learning, in which students regularly participate in the classroom and contribute to the teaching and learning process. Aside from learning by doing (active learning), constructivism promotes social interactions and peer interactions among learners. This learning philosophy supports various ways of communication and engagement. Social constructivism not only respects the learner's individuality and ambiguity, it also promotes, employs, and rewards it as an important part of the learning experience. (Wikipedia, 2020).

2.5 Empirical Studies

Pearson and Kudzai (2015) evaluated the suitability and acceptability of virtual laboratories as alternatives or supplements to the traditional physical laboratories in the teaching of graduates in laboratory-driven science disciplines in Botswana. Participants were drawn from three universities in Gaborone, Botswana. The majority of respondents (66.7%), were faculty staff members and the rest (33.3%), were postgraduate students or recent graduates (0-5 years) at Masters or PhD level in a laboratory-driven science discipline. The majority of respondents (55.6%) believed that the physical laboratories at their universities were not adequate to deliver effective training to postgraduate students in laboratory-driven science disciplines. Despite this, most respondents (52%) were confident that graduates in laboratory-driven science disciplines trained using current laboratory facilities at local universities were equipped to meet industry performance expectations. A significant proportion of respondents (75%), believed that virtual laboratories have a role to play in postgraduate teaching of laboratory-driven science disciplines in Botswana. In terms of the preferred implementation model, the vast majority (94.4%), of respondents favored the

hybrid model combining the use of both virtual and physical laboratories as a permanent set up in the teaching of graduates in laboratory-driven science disciplines.

Gambari *et al*. (2018) investigated the impact of virtual laboratory on the achievements of secondary school chemistry students in homogeneous and heterogeneous collaborative settings in Minna, Niger state, Nigeria. Three hypotheses were formulated, analyzed and tested at 0.05 alpha level. Stratified sampling technique was used to select 60 Senior Secondary Class Two (SS II) Chemistry Students. The subjects were stratified along gender and ability levels. Sixty students were randomly selected from two secondary schools in Minna, Nigeria. Thirty students (male, n = 15; female, n = 15) were selected from each school. Pretest, posttest, and experimental group design was employed. Experts validated 20-item multiple-choice Chemistry Achievement Test (CAT) was used for data collection. Reliability coefficient of 0.91 was obtained from the pilot testing using Kidder Richardson (KR-20). ANCOVA and Side post-hoc statistics were used for testing the hypotheses at 0.05 level of significance. The results showed that: (a) students in homogeneous ability grouping taught Chemistry using virtual laboratory instruction in collaborative setting performed better than their counterpart taught Chemistry in heterogeneous grouping composition. Findings emanating from the study also revealed that female students in homogeneous group performed better than their counterparts in heterogeneous groups. The results of the study also revealed that higher achiever students in homogeneous groups outperformed those in heterogeneous groups.

Yaki *et al*. (2020) investigated the effects of Computer Laboratory Simulation and practical demonstration instructional strategy on the achievement of secondary school students in practical Biology. The research design adopted for the study was Pretest-Posttest

experimental group design. The population is all secondary school students in Minna Metropolis. Purposive sampling technique was used to select two secondary schools in Minna metropolis, Niger State Nigeria. The two Schools were randomly assigned to experimental group (computer simulation group) and control group (Demonstration teaching methods) respectively. Finally, stratified simple random sampling technique was used to select the 60 SSII students. The experimental group had 30 (15 males –15 females) students and control 30 (15 males –15 females) students. A Computer simulation laboratory Package (CSLP) was developed treatment instrument for this study. The instrument that was used in collecting data for the study was researcher adopted Biology Practical Achievement Test (BPAT). The instrument was pilot tested and its reliability coefficient determined as 0.74 using Kuder Richardson (KR-21). The data collected was subjected to analysis using t-test at 0.05 alpha level of significance. The results revealed that there is significant difference between the experimental groups and control group. The experimental group had a significant improvement in performance after they were exposed to treatment. The findings of the study also revealed that there is no significant difference between the male and female students taught practical Biology using computer simulation laboratory.

2.6 Summary of the Literature Reviewed

The research reviewed several literatures on the concept of Biology, Biology curriculum in Nigeria, concept of ICT, ICT in Education, Laboratory in Science education, concept of virtual reality and learning in a virtual environment. Two theories were reviewed which were found to be relevant to the study, these are the constructivism theory and technology acceptance model (TAM), these theories/model built the theoretical framework of the study. The empirical studies reviewed literature on impacts of virtual laboratory on chemistry

students, effects of computer simulation laboratory on Biology students in Minna Metropolis. From the reviewed literature have not been constructed on the effects of virtual laboratory on Biology student's achievement and retention. Hence, this study intends to fill this literature gap and extend the body of existing knowledge by investigating the effect virtual laboratory on achievement and retention of Biology students in senior secondary schools in Minna, Metropolis, Niger State.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Research Design

The researcher used the quasi-experimental design, specifically the pretest, posttest, non-equivalent control group design was used. This implies that, intact classes (non-randomized group) participated in the study. The quasi-experimental design is therefore considered appropriate for this study since intact classes were used.

3.3 Population of the Study

The population for this study consists of all the Biology students in Minna Metropolis, Niger state with a total population of (2170) students which constitute the population of the study (Niger State Educational Data, Senior Secondary Education Board (NSSEB) while the target population comprises second-year secondary school (SSII) Biology students in Mina Metropolis, Niger State.

3.4 Sample and Sampling Technique

A sample refers to a small group of elements drawn through a definite process from a specific population. A sample size of 50 students was drawn from the two schools. To produce the sample, intact classes was employed as the students were sampled using simple random sampling technique; SSII A from the two purposively selected schools, balloting was used to represent the experimental and control groups. The sample for the experimental group of one of the selected schools was used as experimental group and the other as the control group. SSII A of Ideal Royal secondary school, Minna with a class population size of twenty-one

students which formed the experimental group while SSII A of Ahmadu Bahago secondary school, Minna with a class population of twenty-nine students formed the control group.

Table 3.1: Sample Size

S/N	Name of School	Population	Male	Female	Total
1	Ideal Royal School, Minna	21	10	11	**21**
2	Ahmadu Bahago Secondary school, Minna	29	16	13	**29**
Total		**50**	**26**	**24**	**50**

The experimental group were taught using the virtual Laboratory package and the control group were taught using conventional method.

3.5 Research Instrument

An adopted virtual laboratory package was used at the treatment instrument, while the researcher constructed a test instrument; Biology Achievement Test (BAT) and the Biology Retention Test (BRT) were used for data collection. The instrument was constructed by the researcher and it consists of Twenty (20) questions on rabbit. The achievement test and retention test consist of multiple-choice questions with four (4) options (A-D) out of which one serves as the correct answer based on the topic taught (rabbit dissection). However, at the second face (posttest) the options were interchanged likewise the numbering method (reshuffled). Each score per correct answer is one (1) mark. The objective of the topic in Senior secondary school biology curriculum served as a guide for developing the questions.

The items in the BAT and BRT were constructed and tested by the researcher to ensure the inclusion of all the contents of the lessons covered in the topic. The Biology Achievement Test will be used to assess the students' achievement in Biology while the Biology Retention Test (BRT) will be used to assess the students' retention in Biology.

3.6 Validity of Research Instrument

The Biology Achievement Test (BAT) and the Biology Retention Test (BRT), which consists of twenty (20) multiple choice questions was face and content validated by two experts, one (1) expert from the Department of Educational Technology, School of Science and Technology Education (SSTE), Federal University of Technology Minna and a subject expert from FUT Model secondary school. Meanwhile, the virtual laboratory package was validated by two experts in the department of Educational Technology. These experts scrutinized the instruments and made necessary corrections and modification to the subject, proper wording of the items, appropriateness and adequacy of the items for the study, structure and adequate timing. The comments and recommendations of these experts helped to identify and correct the items in the instruments.

3.7 Reliability of the Research Instrument

The reliability of Biology Achievement Test (BAT) and the Biology Retention Test (BRT) was determined through pilot test by administering the instrument to 20 senior secondary school Biology students after instruction with virtual laboratory package in Government Day secondary school, Bosso, Niger State which is not among the sampled schools for the study, a reliability coefficient of 0.89 was determined from the data using Kuder Richardson 21.

3.8 Method of data collection

The school selected was visited by the researcher. Permission was taken from the Principal of the school which was given. The researcher was introduced to the Biology teacher of SSII students. The aim and mode of research was explained to both the teachers and the students for their maximum cooperation. Thereafter, the students were sampled; the students were sampled from the two (2) schools; pretest was administered to the students in order to assess their entry behavior. The test was administered to the two schools used for experimental and control groups in the first week of the visit to the schools. The Biology Achievement Test (BAT) consists of 20 test questions which were drawn from the "Rabbit Dissection" in accordance with SSII Biology curriculum. Each question is followed by four multiple-choice optional answers (A-D) and students were expected to choose the correct answer. Each correct answer chosen earn one mark, zero awarded to any wrong answer chosen and overall score is then converted to percentage. The test lasted for thirty (30) minutes, the lesson commenced in all groups in the second week of experiment which was conducted using the regular period allocated to Biology during class hours. The experiment continued for two (2) weeks followed by revision. The two (2) schools were taught rabbit dissection for this period of two weeks. The experimental group was taught with the virtual laboratory package while the control group was taught without the virtual laboratory package. On the fourth week, posttest was administered to the two schools to test the achievement of the students for both experimental and control groups. The same items contained in the pre-test were used but this time around the questions numbering were reshuffled as well as the options. Each correct answer chosen earn one mark, zero was awarded to any wrong answer chosen and the overall score is then converted to percentage and after two-three weeks the retention test (BRT) was administered to the same group of students to determine their retention ability in both the

experimental and control group respectively. The test lasted for 30 minutes and scripts were collected immediately for scoring.

3.9 Method of Data Analysis

Mean and standard deviation were used to answer the research questions while the independent sample t-test was used to test the hypotheses at 0.05 level of significance. This level of significance formed the basis for rejecting or accepting each of the hypotheses, from which findings, discussions and summary will be arrived at. Computer software Statistical Package for Social Science (SPSS) version 23.00 was used for the analysis.

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

4.1 Result

In this chapter, data for the study were analyzed and presented based on the research questions and hypotheses that guided the study. The research questions were answered using mean and standard deviation while independent statistics was used to test the research hypotheses. All the hypotheses were tested at $P < 0.05$ level of significance.

Table 4.1.1 t-test analysis of pre-test scores of students in the experimental and control group

Group	N	df	$\bar{x}$	SD	t-value	p-value	Decision
Experimental group	21		3.76	1.44			
		48			0.78	0.43	NS
Control group	29		3.44	1.35			

NS=Not Significant at P>0.05

Table 4.1.1 shows the t-test analysis of pretest scores of students in the experimental and control group, with a p-value of 0.43 at p>0.05. this implies that there is no significant difference in the pretest scores of students before the treatment.

Research Question One: What is the mean achievement score of Biology students taught using virtual laboratory and those taught without virtual laboratory? The answer is shown below on table 4.2

Table 4.2 Mean and Standard Deviation of posttest scores of students in the experimental and control group

Group	N	Pretest		Posttest	
		$\bar{x}$	SD	$\bar{x}$	SD
Experimental	21	3.76	1.44	18.33	0.85
Control	29	3.44	1.35	9.72	1.68

Table 4.2 indicates that students taught Biology using Virtual laboratory package has a mean achievement score of 18.33 with a standard deviation of 0.85 at the posttest while those taught using the conventional method had a mean achievement score of 9.72 and a standard deviation of 1.68. from the posttest mean scores, it is revealed that the students that were taught with the virtual laboratory package scored higher than those taught using traditional method.

Research Question 2: What is the mean retention score of Biology students taught using virtual laboratory and those taught without virtual laboratory? The answer is revealed in Table 4.3

Table 4.3 Mean and Standard Deviation of retention test scores of students in the experimental and control group

Group	N	Posttest		Retention	
		$\bar{x}$	SD	$\bar{x}$	SD
Experimental	21	18.85	0.85	17.85	0.85
Control	29	9.72	1.68	8.86	2.54

From Table 4.3, reveals that students taught Biology using the Virtual laboratory package had a higher retention score with a computed mean of 17.85 and standard deviation of 0.85. The control group had a retention mean score was 8.86 and standard deviation of 2.54. The table indicates that students taught Biology using the Virtual laboratory package retained higher than the students taught using conventional method. Table 4.7 reveals the significant difference in retention scores of the experimental and control group.

Research Question 3: Is there any difference in the male and female Biology students mean achievement score taught using virtual laboratory? The answer is revealed in Table 4.4

Table 4.4 Mean and Standard Deviation of male and female achievement scores of students in the experimental group

Group	N	Pretest		Posttest	
		$\bar{x}$	SD	$\bar{x}$	SD
Male	10	3.80	1.61	18.30	1.05
Female	11	3.72	1.34	18.36	0.67

Table 4.4 reveals the influence of gender on the mean achievement scores of students taught using the Virtual laboratory package. The male students had a mean achievement score of 18.30 and a standard deviation of 1.05 at the posttest, the female students had a mean achievement score of 18.36 and a standard deviation of 0.67. This indicates that females achieved higher than their male counterparts.

Research Question 4: Is there any difference in the male and female Biology students mean retention score taught using virtual laboratory? The answer is revealed in Table 4.5

Table 4.5 Mean and Standard Deviation of male and female retention scores of students in the experimental group

Group	N	Posttest		Retention	
		$\bar{x}$	SD	$\bar{x}$	SD
Male	10	18.30	1.05	17.70	0.67
Female	11	18.36	0.67	18.00	1.00

Table 4.5 presents the influence of gender on the mean achievement scores of students taught using Virtual laboratory package. The male students had mean retention score of 17.70 and a standard deviation of 0.67 while the females had a mean of 18.00 and a standard deviation of 1.00. This indicated that the female students retained higher than the males.

4.2 Hypothesis Testing

HO_1: There is no significant difference between the mean achievement score of Biology students taught using virtual laboratory and those taught without virtual laboratory

Table 4.6 T-test for the posttest achievement scores of the experimental and control groups

Group	N	df	$\bar{x}$	SD	t-value	p-value
Experimental group	21		18.33	0.85		
		48			21.41	0.00
Control group	29		9.72	1.68		

Significant at $p < 0.05$

Table 4.6 shows the t-test analysis of students taught Biology using the Virtual laboratory package and those taught using convention method. The result revealed that t-value is 21.41 and p-value of $0.00 < 0.05$. Therefore, the null hypothesis was rejected, this indicated that there is a significant difference in the mean achievement test of students taught using virtual laboratory and those without it.

Hypothesis 2: There is no significant difference in the mean retention score of Biology students taught using virtual laboratory and those taught without virtual laboratory

Table 4.7 T-test for the posttest retention scores of the experimental and control groups

Group	N	Df	$\bar{x}$	SD	t-value	p-value
Experimental group	21		17.85	0.85		
		48			15.53	0.00
Control group	29		8.86	2.54		

Significant at $p < 0.05$ level

The t-test for table 4.7 shows the mean retention scores of students taught Biology using the Virtual laboratory package and those taught using convention method. There was a significant difference between the mean retention scores of students taught Biology using virtual laboratory package and those taught using conventional teaching methods as determined by the t-test analysis with a t-value at 15.53 and a p-value of $0.00 < 0.05$. students taught using virtual laboratory package (M=17.85, S. D=0.85) scoring higher than students taught using the conventional method (M=8.86, SD=2.54). Therefore, the null hypothesis was rejected, this indicated that there a significant difference between the mean retention scores of students taught Biology using virtual laboratory package and those taught using conventional teaching methods.

Hypothesis 3: There is no significant gender difference in the mean achievement score of Biology students taught using virtual laboratory and those taught without virtual laboratory

Table 4.8 T-test analysis of male and female students taught Biology using Virtual laboratory package

Gender	N	Df	$\bar{x}$	SD	t-value	p-value	Decision
Male	10		18.30	1.05			
		19			-0.16	0.87	NS
Female	11		18.36	0.67			

NS= Not Significant at p > 0.05 level

The t-test for table 4.8 shows the mean achievement scores of male and female students taught Biology using the Virtual laboratory package. There was no significant difference between the mean achievement scores of male and female students taught Biology using Virtual laboratory package as determined by the t-test analysis with a t-value at -0.16 and a p-value of 0.87 > 0.05. Male students (M=18.30, S.D=1.05) while the female students (M=18.36, SD=0.67). Therefore, the null hypothesis was not rejected, this revealed that there was no significant difference between the mean achievement scores of male and female students taught Biology using Virtual laboratory package.

Hypothesis 4: There is no significant gender difference in the mean retention score of Biology students taught using virtual laboratory and those taught without virtual laboratory

Table 4.9 Retention t-test analysis of male and female students taught Biology using Virtual laboratory package

Group	N	Df	$\bar{x}$	SD	t-value	p-value	Decision
Male	10		17.57	0.67			
		19			-0.79	0.43	NS
Female	11		18.00	1.00			

NS= Not Significant at p > 0.05 level

The t-test for table 4.9 shows the mean retention scores of male and female students taught Biology using the Virtual laboratory package. There was no significant difference between the mean retention scores of male and female students taught Biology using Virtual laboratory package as determined by the t-test analysis with a t-value at -0.79 and a p-value of 0.43 > 0.05. Male students (M=17.70, S.D=0.67) while the female students (M=18.00, SD=1.00). Therefore, the null hypothesis was not rejected, this indicates there was no significant difference between the mean retention scores of male and female students taught Biology using Virtual laboratory package.

4.5 Discussion of Findings

The data analyzed in this chapter were interpreted and discussed on the results derived from four research questions and hypotheses. The main objective of the research is to determine the effect of Virtual laboratory package on student's achievement and retention in the teaching of Biology. The posttest scores in table 4.2 shows that the experimental group (M=18.33, S.D=0.85) had a higher achievement scores than the control group (M=9.72,

S.D=1.68). Similarly, the p-value associated with the calculated value of t.val (21.41) in table 4.6 is 0.00 which is less than the level of significance, the null hypothesis was therefore rejected. Hence, there is significant difference in the mean achievement scores of students taught Biology with the use of Virtual laboratory package. The finding of this study is in line with the findings of Gambari et al. (2018) who revealed the use of Virtual laboratory package therefore has a significant effect on student's achievement in Biology as compared to conventional teaching method.

The experimental retention group scores at the posttest level in table 4.3 shows that the experimental group (M=17.85, S.D=0.85) had a higher achievement scores than the control group (M=8.86, S.D=2.54). Similarly, the p-value associated with the calculated value of t.val. (15.53) in table 4.7 is 0.00 which is less than the level of significance, the null hypothesis was therefore rejected. Hence, there is significant difference in the mean retention scores of students taught Biology with the use of Virtual laboratory package. The finding of this study is in line with the findings of Gambari et al. (2018) who revealed that the use of Virtual laboratory package therefore has a significant effect on student's retention in Biology as compared to conventional teaching method.

The female students at posttest level (M=18.36, S.D=0.67) achieved higher than the male Biology students (M=18.30, S.D=1.05). Although, the p-value revealed there was no significant difference (p=0.87), in table 4.8 the p-value was greater than the 0.05 level of significance hence, the null hypothesis was accepted. The finding of this study is in line with the findings of Yaki et al. (2020) who revealed that there is no significant difference in the mean achievement scores of male and female Biology students.

The mean retention score of male students exposed to the Virtual laboratory package (M=17.70, S.D=0.67) while the mean scores of female students (M=18.00, SD=1.00). Similarly, the value associated with the value of t (t.val=, df=, p>0.23). In table 4.9, the p-value is greater than the level of significance (0.05), hence the null hypothesis was accepted. This indicates that there is no significant difference in the mean retention score between male and female students taught using Virtual laboratory package.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The research determines the effects of virtual lab on the achievement and retention of biology students in senior secondary schools in Minna, metropolis, Niger state. This chapter contains the summary, conclusion, recommendation, major findings of the study, contribution to knowledge, implications of the findings and suggestions for further studies.

5.1.2 Conclusion

Based on the findings and discussion of the study, the following conclusion were drawn;

The effective and adequate use of Virtual laboratory package improves the academic achievement and retention in Biology students. The evidence of the experimental group that use the Virtual laboratory package in teaching enhances student's achievement more than the convention method. The use of Virtual laboratory package has a great significant effect on student's retention level and also on achievement in Biology. Emphasis should be laid on the use of virtual laboratory package for teaching Biology in senior secondary schools.

1.1 Recommendation

In view of this project findings, the following recommendations was made;

1. In-service training should be organized for teachers so that they learn the process of producing virtual laboratory package and the use of modern instructional media for effective instructional delivery.

2. Seminars, conference and workshops should be organized and put in place for the teachers on the use of Virtual laboratory package as instructional materials
3. There should be adequate reinforcement to hardworking and dedicated teachers through prize awards as a means of appreciation.
4. Government, school administrators should show support and dedication to encourage creativity shown by co-science teachers by providing teaching materials which will promote science and technology in Nigeria.

1.2 Major Findings of the Study

The following findings have been made from the research work

1. There was significant difference between the mean achievement scores of students taught Biology using Virtual laboratory package and those taught using conventional method
2. There was significant difference between the mean retention scores of students taught Biology using Virtual laboratory package and those taught using conventional method
3. There was no significant difference between the mean achievement scores of male and female students taught Biology using virtual laboratory package.
4. There was no significant difference between the mean retention scores of male and female students taught Biology using virtual laboratory package.

1.3 Contribution to Knowledge

The result of the study has contributed to knowledge in the following ways

1. Helping the teacher understand the use of instructional materials and Virtual laboratory package will reduce the abstract nature of Biology concepts thereby making learning interesting.
2. Adequate use of virtual laboratory package will help save the teacher's time and energy
3. Retention of students during learning activities can be enhanced through the use of virtual laboratory package
4. It helps to contribute to the existing literature and use to provide platform for further research.

1.4 Implications of the Findings

Various implications have been adopted but the most important is the use of virtual laboratory package in teaching Biology in senior secondary schools so as to improve student's achievement and retention level in Biology. Therefore, teachers should be encouraged and enlightened on the use of virtual laboratory package as it creates interaction between the teacher and the students. It can also be used to enhance the student knowledge and enables them to contribute their own quota on whatever they are been taught.

1.5 Suggestions for further Research

Areas where further research could be done are as follows;

1. Effects of virtual laboratory on the achievement and retention of students on other subjects such as Chemistry, Physics, Mathematics among others.
2. Effect of virtual laboratory package in teaching and its achievement, retention and interest on student's performance

3. Effects of virtual laboratory on the achievement and retention of Biology student in Niger State and North-central.

REFERENCES

Abimbola I. O., & Mustapha, M. T. (2003). The use of analogies in communicating difficult science concepts to secondary school students. The Nigerian Teacher Today 9(1), 67-68

Abungu, H. E., Okere, M. I., & Wachanga, S. W. (2014). Effect of science process skills teaching strategy on boys and girls' achievement in chemistry in Nyando district, Kenya. Journal of Education and Practice, 5(15), 42-48.

Adigun, J., Onihunwa, J., Irunokhai, E., Sada, Y., & Adesina, O. (2015). Effect of Gender on Students' Academic Performance in Computer Studies in Secondary Schools in New Bussa, Borgu Local Government of Niger State. Journal of Education and practice, 6(33), 1-7.

AIBARA, H. D. (2017). To study the impact of information and communication technology ICT as a subject in std x students of Maharashtra state board ssc schools in Mumbai.

Aina, J. K., & Akintunde, Z. T. (2013). Analysis of gender performance in physics in colleges of education, Nigeria. Journal of Education and practice, 4(6), 1-5.

Ajaja, O. P. (2007). Teaching methods across disciplines. Agbor: All-well Publishers.

Akintola, D. A. (2017). The status of biology in nigerian secondary school curriculum: implications for scientific literate society. Journal of Curriculum and Instruction, 10(2).

Al-Hassan, K. E. E. (2016). The Impact of Virtual Laboratories on Academic Achievement and Learning Motivation in the Students of Sudanese Secondary School. International Journal of English Language, Literature and Humanities, 4(9).

Alphin, H. C. (2014). Global accreditation for a knowledge-oriented community: Foundational change breeds global access to educational and economic opportunity. In Handbook of Research on Transnational Higher Education (pp. 303-328). IGI Global.

Auer, M., Pester, A., Ursutiu, D., & Samoila, C. (2003, December). Distributed virtual and remote labs in engineering. In IEEE International Conference on Industrial Technology, 2003 (Vol. 2, pp. 1208-1213). IEEE.

Awosika, I. F. (2008). The contributions of biological science to national development: Nigerian experience. Ife Journal of Science, 10(1), 97-101.

Ayodele, O. D. (2018). Re-structuring secondary school chemistry education for sustainable development in Nigerian developing economy. African Journal of Chemical Education, 8(2), 93-111.

Bardi, J. (2019) What is Virtual Reality? [Definition and Examples]. Marxentlabs. Retrieved 19th May, 2021 from https://www.marxentlabs.com/what-is-virtual-reality/

Bima, M., Saputro, H., & Efendy, A. (2021). Virtual Laboratory to Support a Practical Learning of Micro Power Generation in Indonesian Vocational High Schools. Open Engineering, 11(1), 508-518.

Bohil, Corey & Owen, Charles & Jeong, Eui & Alicea, Bradly & Biocca, Frank. (2009). Virtual Reality and Presence. 10.4135/9781412964005.

Cheng, Y., & Wang, S. H. (2011). Applying a 3D virtual learning environment to facilitate student's application ability–The case of marketing. Computers in Human Behavior, 27(1), 576-584.

Cimer A.I. (2012). What makes biology learning difficult and effective: Studentsâ€™ views. Educational research and reviews, 7(3), 61-71.

Dalgarno, B., Bishop, A. G., Adlong, W., & Bedgood D. R. (2009). Effectiveness of a virtual laboratory as a preparatory resource for distance education chemistry students, Computers & Education, 53(3), 853–865.

Dania, P. O. (2014). Effect of gender on students academic achievement in secondary school social studies. Journal of Education and Practice, 5(21).

DeBoer, G. E. (1991). A history of ideas in science education: Implications for practice. New York: Teachers College Press

Diwakar, S., Achuthan, K., Nedungadi, P., & Nair, B. (2012). Biotechnology Virtual Labs: facilitating laboratory access anytime-anywhere for classroom education. In Innovations in biotechnology (pp. 379-398). InTech..

Ebonam, C. R., & Nwanneka, O. J. Effects Of Instructional Computer Animation On Secondary School Students' Achievement In Chemistry In Awka Education Zone.

Elisha, M. J. (2006). The application of Information and Communication Technology (ICT) in Nigerian academic libraries prospects and problems. Information Manager (The), 6(1), 35-39.

European Schoolnet (EUN) (2003). Virtual Learning Environments for European Schools, Brussels, European Schoolnet. Retrieved April 24, 2021 from http://www.unideusto.org/tuningueu/teaching-learning-a-assessment.html.

Federal Republic of Nigeria (FRN). (2013). National Policy on Education. Lagos: NERDC press.

Fu, J. (2013). Complexity of ICT in education: A critical literature review and its implications. International Journal of education and Development using ICT, 9(1), 112-125.

Gambari, A. I., Kawu, H., & Falode, O. C. (2018). Impact of Virtual Laboratory on the Achievement of Secondary School Chemistry Students in Homogeneous and Heterogeneous Collaborative Environments. Contemporary Educational Technology, 9(3), 246-263.

Ghavifekr, S., & Rosdy, W. A. W. (2015). Teaching and learning with technology: Effectiveness of ICT integration in schools. International Journal of Research in Education and Science, 1(2), 175-191.

Glory, G.-E., & Sopuruchi, I. (2017). Influence of Gender on Interest and Academic Achievement of Students in Integrated Science in Obio Akpor Local Government Area of Rivers State. European Scientific Journal, ESJ, 13(10), 272. https://doi.org/10.19044/esj.2017.v13n10p272

Gomes, L., & Murphy, J. (2003). An exploratory study of marketing international education online. International Journal of Educational Management.

Gongden, E. J., Oloyede O. I. & Ephraim, E. G (2011). Evaluation of Chemistry teachers' use of concept mapping strategy in secondary schools in plateau state – nigeria. International Journal of Advanced Research. 4(12), 1880-1887

Hallyburton, C., & Lunsford, E. (2013). Challenges and Opportunities for Learning Biology in Distance-Based Settings. Journal of Biology Based Teaching, 39(1), 27-33

Hassan, M., & Salihu, N. Assessing River Water Quality using Weighted Arithmetic Water Quality Index in River Gada, Katsina State, Nigeria.

Hofstein, A. (2017). The role of laboratory in science teaching and learning. In Science education (pp. 355-368). Brill Sense.

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. Science education, 88(1), 28-54.

https://researchcyber.com/icr-

Ityokyaa, F. M., & Adejoh, M. J. (2014). Evaluation of the implementation of biology programme in secondary schools in Benue State of Nigeria. Journal of Modern Education Review, 4(11), 970-977.

Jenkins, E. W. (2013). The 'nature of science'in the school curriculum: The great survivor. Journal of curriculum studies, 45(2), 132-151.

Jeschke, S., Richter, T., & Zorn, E. (2010). Virtual labs in mathematics and natural sciences. International Conference on Technology Supported Learning & Training: Online Educa Berlin. Retrieved February 10, 2010, from: http://www.ibi.tu-berlin.de/diskurs/veranst/online_educa/ oeb_04/Zorn%20TU.pdf

JISC, (2000). Managed Learning Environments: A workshop run by JISC Assist, 29 February and 7 March 2000. Final Report. JISC. Retrieved March 26, 2021 from http://www.jisc.ac.uk/index.cfm?name=mle_briefings_2.

KILIÇ, T. (2016). The concept of virtual reality as interior interface. *Conference Proceedings*: All In One Conferences Zagreb 2016

Kolil, V. K., Muthupalani, S., & Achuthan, K. (2020). Virtual experimental platforms in chemistry laboratory education and its impact on experimental self-efficacy. International Journal of Educational Technology in Higher Education, 17(1), 1-22.

Konrad, (2003). Review of educational research on virtual learning environments (VLE) – implications for the improvement of teaching and learning and access to formal learning in Europe. Paper presented at the European Conference on Educational Research, University of Hamburg, 17 -20 September 2003. Retrieved September 15, 2021 from http://www.leeds.ac.uk/educol/documents/00003192.htm.

Larbi-Apau J. (2020). Virtual science labs are real and can be used in blended learning. University World News. Retrieved 19th May, 2021 from https://www.universityworldnews.com/post.php?story=20200630093204248

Lestari, D. P. (2020). Students and teachers' necessity toward virtual laboratory as an instructional media of 21st century science learning. In Journal of Physics: Conference Series (Vol. 1440, No. 1, p. 012091). IOP Publishing.

Lunetta, V. N., Hofstein, A., & Clough, M. P. (2007). Learning and teaching in the school science laboratory: An analysis of research, theory, and practice. Handbook of research on science education, 2, 393-441.

Manca, D., Totaro, R., Nazir, S., Brambilla, S., & Colombo, S. (2012). Virtual and augmented reality as viable tools to train industrial operators. In Computer aided chemical engineering (Vol. 31, pp. 825-829). Elsevier.

Maulidah, S. S., & Prima, E. C. (2018). Using Physics Education Technology as a Virtual Laboratory in Learning Waves and Sounds. Journal of Science Learning, 1(3), 116-121.

Mouhamad, Raghad. (2018). Biology lecture. Researchgate. Retrieved 21st March, 2021 from https://www.researchgate.net/publication/327955053_Biology_lecture

Muhanna, M. A. (2015). Virtual reality and the CAVE: Taxonomy, interaction challenges and research directions. Journal of King Saud University-Computer and Information Sciences, 27(3), 344-361.

National Research Council (NRC). (2007). Taking Science to School: Learning and Teaching Science in Grades K-8. Washington, DC: National Academies Press

Negi, P. S., Negi, V., & Pandey, A. C. (2011). Impact of information technology on learning, teaching and human resource management in educational sector. International Journal of Computer Science and Telecommunications, 2(4), 66-72.

NGSS Lead States. (2013). Next Generation Science Standards: For States, By States. Washington, DC: National Academies Press

Nigerian Educational Research and Development Council (NERDC) (2009). Senior Secondary School Curriculum: Fishery for SSS1-3. Sheda, Abuja: University Press Plc

Nwabude, A. A., Ogwueleka, F. N., & Irhebhude, M. (2020). The use of virtual learning environment and the development of a customised framework/model for teaching and learning process in developing countries. Education, 10(1), 1-12.

Nweke, M. N., & Ifeanyi, A. N. Effects of Computer Assisted Instruction (CAI) On Achievement and Retention of Students with Hearing Impairment in Computer Studies.

Oh, H., Yoon, S. Y., & Hawley, J. (2004). What virtual reality can offer to the furniture industry. Journal of Textile and Apparel, Technology and Management, 4(1), 1-17.

Oliver, R., & Harrington, J. (2003). Exploring technology-mediated learning from a pedagogical perspective, Interactive Learning Environments, Vol. 11(2), 111-126.

Oser, F. (2013). “I Know How to Do It, But I Can’t Do It”: Modeling Competence Profiles for Future Teachers and Trainers. In Modeling and measuring competencies in higher education (pp. 45-59). Brill Sense.

Pareek, R. B. (2019). An assessment of availability and utilization of laboratory facilities for teaching science at secondary level. Science Education International, 30(1).

Pearson, C., & Kudzai, C. (2015). Virtual Laboratories a Solution for Tertiary Science Education in Botswana.

Pearson, C., & Kudzai, C. (2015). Virtual Laboratories a Solution for Tertiary Science Education in Botswana.

Peng, Q. (2007). Virtual Reality Technology in product design and manufacturing. Proceedings of the Canadian Engineering Education Association (CEEA).

Pratt, M. K. (). ICT (information and communications technology, or technologies). Techtarget. Retrieved 5th May, 2021 from https://searchcio.techtarget.com/definition/ICT-information-and-communications-technology-or-technologies

Raja, R., & Nagasubramani, P. C. (2018). Impact of modern technology in education. Journal of Applied and Advanced Research, 3(1), 33-35.

Ramadhan, M. F. & Irwanto (2017). Using virtual labs to enhance students' thinking abilities, skills, and scientific attitudes. In International Conference on Educational Research and Innovation (ICERI 2017) (pp. 494-499).

Reisoğlu, I., Topu, B., Yılmaz, R., Yılmaz, T. K., & Göktaş, Y. (2017). 3D virtual learning environments in education: A meta-review. Asia Pacific Education Review, 18(1), 81-100.

Rogers, K. , Joshi, . Susan Heyner and Green, . Edna R. (2021). Biology. Encyclopedia Britannica. https://www.britannica.com/science/biology

Scheurs, J., & Dumbraveanu, R. (2014). A shift from teacher centered to learner centered approach. learning, 1(2).

Sclater, N. (2009). Principles for the future VLE/LMS development/virtual learning, Retrieved March 27, 2010, from http://www.sclater.com/blog/?p=210.

Serdyukov, P. (2017). Innovation in education: what works, what doesn’t, and what to do about it?. Journal of Research in Innovative Teaching & Learning.

Subramanian, R., & Marsic, I. (2001). VIBE: Virtual biology experiments. Retrieved August 10, 2010, from http://www.hkwebsym.org.hk/(2001)/E4-track/vibe.pdf.

Suleman, Q., Hussain, I., Din, M. N. U., & Iqbal, K. (2017). Effects of Computer-Assisted Instruction (CAI) on Students' Academic Achievement in Physics at Secondary Level. Computer Engineering and Intelligent Systems, 8(7), 9-17.

Summak, M. S., Bağlıbel, M., & Samancıoğlu, M. (2010). Technology readiness of primary school teachers: A case study in Turkey. Procedia-Social and Behavioral Sciences, 2(2), 2671-2675.

Tatli, Z., & Ayas, A. (2013). Effect of a virtual chemistry laboratory on students' achievement. Journal of Educational Technology & Society, 16(1), 159-170.

Tatli, Z., & Ayas, A. (2013). Effect of a virtual chemistry laboratory on students' achievement. Journal of Educational Technology & Society, 16(1), 159-170.

Tüysüz, C. (2010). The Effect of the Virtual Laboratory on Students' Achievement and Attitude in Chemistry. *International Online Journal of Educational Sciences*, 2(1).

Ugwuanyi, C. S., & Okeke, C. I. (2020). Enhancing University Students' Achievement in Physics Using Computer-Assisted Instruction. International Journal of Higher Education, 9(5), 115-124.

Umana, K. (2018). ICT resources for sustainable development in Nigeria. Retrieved from

UNESCO (2021). Expression of Interest - Provision of services for "Defining Basic Technical Standards for Tools of Information and Communication Technologies in Education Systems in Bosnia and Herzegovina". UNESCO. Retrieved 13th March, 2021 from https://en.unesco.org/news/expression-interest-provision-services-defining-basic-technical-standards-tools-information-and

Vidhate (2019). The role of information and communication technologies in teaching and learning. *International Journal of Contemporary Studies*. ISSN 2456-0960.

Wikipedia contributors. (2021). Virtual learning environment. In Wikipedia, The Free Encyclopedia. Retrieved 16:58, August 5, 2021, from https://en.wikipedia.org/w/index.php?title=Virtual_learning_environment&oldid=1026425522

Woodfield, B. (2005). Virtual chemlab getting started. Pearson Education Website. Retrieved May 25, 2021, from http://www.mypearsontraining.com/pdfs/VCL_getting_started.pdf

Yaki, A. A., Babagana, M., & Abubakar, Z. (2020). Effects of Virtual Laboratory Simulation Package and Demonstration Instructional Strategy on the Achievement of Secondary School Students in Biology.

Yu, J.Q, Brown, D. J., & Billet, E.E. (2005). Development of virtual laboratory experiment for biology. European Journal of Open, Distance and E-Learning, 1–14.

Zaturrahmi, Z., Festiyed, F., & Ellizar, E. (2020). The Utilization of Virtual Laboratory in Learning: A Meta-Analysis. Indonesian Journal of Science and Mathematics Education, 3(2), 228-236.