

Chapter One

Introduction

1.1 Background to the Study

Academic achievement, in a literal sense, refers to students' learning outcomes, which are measured through assessments that reflect basic knowledge acquisition, competence and skills development. The importance of achievement is well noted in science subjects such as Physics, Chemistry and Biology, where the understanding of concepts is necessary for higher learning and professional competence. Various studies indicated that a variety of teaching methods influences academic achievement, the condition of the learning environment and motivation on the part of the learners. Studies also indicate that through innovative teaching strategies, students often achieve higher educational achievement than their counterparts, particularly when these methods emphasis experimental learning¹.

To improve academic achievement in Chemistry, especially Volumetric analysis, a suitable method of instruction must be ensured by the teachers handling the aspect, as it is time-demanding and requires a lot of concentration and effort towards achieving the desired result and efficient learning outcome. This, in turn, will not only improve students' academic achievement but will also go a long way in contributing to the technological advancement of the Nation ².

Volumetric analysis is a practical aspect of Chemistry that deals with volume measurement, the determination of the concentration of a solution and fundamental calculations to determine the endpoint of neutralisation. This requires setting the laboratory with the needed equipment and materials that are crucial in carrying out the practical exercise³. However, students' achievement over the years in the practical

aspect of Chemistry, especially Volumetric Analysis (Acid–Base titration), is not encouraging as students' achievement falls below expectations.

Various instructional strategies have been introduced in recent years to improve students' academic achievement in science, including inquiry-based learning, project-based learning, cooperative learning, among others⁴. Inquiry-based learning encourages students to explore scientific questions, fostering critical thinking and problem-solving skills. Project-based learning involves students in real-world problems, leading to deeper understanding and long-term retention of knowledge⁵. Cooperative learning strategies have also proven effective by encouraging peer interaction, which reinforces understanding⁶. Despite these advances, research reveals mixed outcomes, as not all students benefit equally from these methods. Consequently, strategies like virtual learning platforms are emerging as important, effective alternative approaches to address the gaps in traditional learning methods, especially in topics like Volumetric Analysis, where visual and interactive content can aid teaching and learning of Chemistry⁷.

The study of matter and natural events, which relies primarily on the empirical observation, and qualitative and quantitative measurements, is called chemistry. A lot of technical/basic tools and equipment operate in accordance with the laws and theories of Chemistry⁸. The findings of scientific research have shaped the aspects of science and the aspects have been considerably implemented in our lives. Chemistry knowledge is required in Medicine, Nursing, Pharmacy, Agriculture, Engineering and the like. The subject is the one that needs the methods of science to unfamiliarised the theoretical concepts and how they apply to practical problems that arise in our daily lives.

Chemistry is taught to Students in Nigerian secondary schools, in a three-year

period, Senior Secondary School one through three as required by the National Policy on Education⁹. It is on this basis that during this time, the teachers of Secondary Schools are obliged and expected to have students participating in Laboratory work of an experimental nature with the object of acquiring and improving their scientific knowledge and experimental skills and at the same time the stimulation and maintenance of interest that students may have in the subject and the attitude of students towards chemistry and chemistry related disciplines, like Physics and Biology, on a positive note. This value has been well articulated in the fifth section of the updated version of the National Policy on Education by the Federal Governments in Nigeria in terms of the teaching and learning of science⁹.

The introduction of chemistry as a major subject to students inclined to sciences into the Nigerian education system necessitates the research into the effective method of teaching the subject. The reason is that there are both personal and societal values in effective chemistry learning. Various approaches and techniques have been embraced in order to help students in the learning and comprehending process of Chemistry¹. However, majority of the students are still under-achievers in chemistry but this is not expected of them.

A functional laboratory is well equipped with the basic requirements, such as water, gas, electricity and other apparatus, with qualified laboratory personnel to oversee the activities of students and ensure its operations². Chemistry educators, school Administrators, and curriculum planners need to seek suitable teaching methods of tackling the current mass failure if they are to halt the drift of students to arts and social science subjects. This paper, thus, aims to investigate the effectiveness of improvised teaching and virtual laboratory-based instructional learning strategies that may help students learn and apply fundamental skills to solve problems in

chemistry. Improvised instructional materials should be designed to engage students' minds, so that each student may acquire necessary skills and competence in areas of measurement of physical quantities with appropriate accuracy, precision, manipulation of materials, apparatus, tools and measuring instruments, clear description of their observations and measurements, representation of information in appropriate verbal, pictorial, graphical and mathematical terms¹⁰.

Theory and research suggest that meaningful learning is possible in laboratory activities if all students are provided with opportunities to manipulate equipment and materials, while working cooperatively with peers in an environment in which they are free to pursue solutions to problems that interest them¹¹. For students to acquire the manual and mental skills associated with learning chemistry, it is essential that students be fully engaged in improvised laboratory activities. This involves improvised apparatus, equipment and laboratory stations for activity groups containing not more than five students and adequate safety measures that are put in place in the physical laboratory settings to ensure an accident-free learning environment.

The number of students in a laboratory stationed in a classroom should be small enough for the teacher to supervise the students' activities effectively, having sufficient time to actively work with each laboratory activity group¹². Chemistry teachers must ensure equal access to laboratory activities under appropriate supervision for all students.

Computers and modern instruments should be provided in school laboratories for effective teaching and learning of the subject. Although Chemistry learning can take place using the simplest equipment, computers and measuring instruments incorporating modern technology can be powerful tools for learning Chemistry

concepts and developing skills of measurement, analysis, evaluation, and processing of data and information¹³. However, the use of Computer should not replace laboratory practices and experience, but can be useful in data analysis and evaluation and serve as supplements in cases where improvised materials is unavoidably absent in a Chemistry Laboratory.

In terms of checking students learning outcomes, evaluation of student learning in Chemistry should include assessment of skills developed in laboratory activities and the knowledge acquired during these activities. Test questions relating and structured directly to laboratory/practical work should not only address laboratory learning, but also communicate the importance of laboratory work to students¹⁴. To enhance effective laboratory activities, it is expected that teachers, technologists and instructors, have adequate and convenient storage facilities that can provide first hand access to apparatus, equipment and materials through cataloguing. A workspace with tools for repairs, maintenance, or construction of equipment, set up and carrying out laboratory experiments prior to classes is equally necessary and important for teaching and learning activities to be effectively carried out in Chemistry¹⁵.

In order to maintain students' skills and keep abreast of new developments in chemistry teaching, teachers need time, funds, support, motivation and encouragement to participate in appropriate professional activities. These may include attendance at workshops and professional conferences; examining new laboratory equipment, curricula, texts, resource materials, working and consulting with colleagues in schools and colleges and other science related subjects such as Physics and Biology¹⁶. Moreover, when students were given a well-designed laboratory exercise, they can carry out experimental activities and engage, both individually and collaboratively, in open-ended laboratory and inquiry-based learning activities that apply theoretical

concepts to relevant, real-life problems. The aims of laboratory practices in chemistry education have also been classified under four categories such as actualising the conceptual learning, attaining technical skills, attaining research skills and producing effective learning products.

Moreover, laboratory tests can be used to make students learn abstract notions in chemistry. Students find practical work interesting and fun in a way that they will be motivated in exploring the material that is related to the topics in the classroom. Laboratory exercises prompt students to think tactically and solve the problems with minimal or no supervision, discover the facts and new principles, learn to cooperate, and learn to think critically of the matter. However, the participation of the teachers in making the students realize these good goals of the practical work is highly relevant and essential¹⁷.

Chemistry laboratory experiments are important in school because they stimulate students' enthusiasm for learning, improve learning efficiency and develop their observations and thinking abilities. These experiments are a basic content of chemistry teaching and cultivate students' spirit of study. They also provide opportunities for students to apply analytical skills that can be used in all areas of their lives, including social dimensions. Additionally, Chemistry laboratory experiments offer a unique way to bring students closer to science and in choosing careers that are expected of them in the nearest future, even if they cannot visit research facilities in person. Through these experiments, students can gain a deeper understanding of concepts, theories and laws, enhance their scientific thinking ability and improve their inquiry skills. Overall, improvised laboratory experiments play a crucial role in fostering a culture of integrated chemistry education and preparing students for future scientific endeavors¹⁸.

Among the functions of teachers is to establish favourable learning conditions in laboratory in order to deliver optimal education to the low-achieving science students. There is an opportunity to enhance science when laboratory experiences can give opportunity to: ask research questions, apply laboratory tools and procedures, make observations, collect and analyse data, verify, test or evaluate explanatory models (including verifying known scientific theories and laws), hypotheses, design investigations, and construct explanatory models¹⁹.

In order to ensure effective teaching and learning process in Chemistry, groups of objectives that may be achieved through the use of the laboratory in science classes includes: Skills (manipulative, inquiry, investigative, organisational and communicative), Concepts (hypothesis, theoretical model and taxonomic category), Cognitive abilities (critical thinking, problem solving, application, analysis and synthesis), Understanding the nature of science (scientific enterprise, scientists and how they work, existence of a multiplicity of scientific methods, interrelationships between science and technology and among the various disciplines of science and Attitudes - for example, curiosity, interest, risk taking, objectivity, precision, confidence, perseverance, satisfaction, responsibility, consensus, collaboration, and special interest in science.

In a Laboratory teaching at the college level, it was observed that science laboratory equipment is a special-purpose tool used in performing experiments. These tools include many different instruments that help students conduct experiments and observe how other physical processes work. The laboratory consists of duration, measurement, identification, dissolution and testing. Laboratory teaching assumes that first-hand experience in observation and manipulation of the materials of science is superior to other methods of developing understanding and appreciation. Laboratory

training is also frequently used to develop skills necessary for more advanced study or research. From a theoretical standpoint, the activity of the student, the sensorimotor nature of the experience, and the individualisation of laboratory instruction should contribute positively to learning²⁰.

Information cannot usually be obtained, however, by direct experience as rapidly as it can be from abstractions presented orally or in print. Thus, one would not expect laboratory teaching to have an advantage over other teaching methods in the amount of information retention, in the ability to apply learning, or in actual skill in observation or manipulation of materials.

Misconceptions about the use of the laboratory in science need to be justified. One is whether laboratories somehow "illustrate" lecture courses - a function that is not possible in a simple, one-afternoon exercise. It was contended that most scientific theories are based on a large number of very sophisticated experiments²¹. If lecture topics are to be illustrated, this should be done through the use of audio-visual aids or demonstrations. The second misconception is whether laboratories exist to teach manipulative skills. It was argued that the majority of students in science laboratory classes do not have a career goal of becoming professional scientists²¹. Furthermore, many of the skills students learn in laboratories are obsolete in science careers. If these skills are worth teaching, there are tools to be mastered for basic scientific inquiry and not as ends in themselves.

Experimental activities are important and of great impact in the teaching and learning of chemistry as they help students learn and achieve even better since the activities make the content more meaningful. Hands-on laboratory instruction has been acknowledged as an important part of education since the 19th century to enable students to venture into the intricacies of the natural world. Students also acquire vital

skills of scientific inquiry through experimental practices that include observation, inference or conclusion, prediction, communication, analysis, and critical thinking as part of the scientific process. The abilities also support analytical thinking and involvement in scientific investigation. Moreover, the experimental activities assist in the translation of the abstract concepts to practice, support learning in the classroom and relate chemistry with its application in the real world.

In view of these advantages, the curriculum planners find it appropriate to put in place such provisions that students who want to gain admission to the higher degrees must have a credit pass in science courses in senior secondary schools in Nigeria. The access to improvised laboratory tools allows students to enhance their learning by conducting practical tests because they study chemical substances, examine orchestrations involving inorganic reactions, examine organic molecules, and use the principles of chemistry. This practice model links theory with practice, encourages self-research, and enhances the proficiency of the students in the laboratory significantly²¹.

Whilst laboratory experiments have numerous advantages to both teachers and learners, much of chemistry experiments are not done in poor countries like Nigeria due to lack of resources, safety and logistical issues. The high price of acquiring chemicals and equipment in Nigerian secondary schools forms a barrier because students are only able to do few experiments as opposed to countries where ample provision of laboratory materials and facilities is in place to teach and learn Chemistry. Failure of the students to be exposed to the practical experience kills the students' interest in the chemistry, hinders the capability of the teachers to deliver effective teaching in chemistry and the standard of acquisition of practical skills on the learners and also blocks the employment in the industrial jobs who require the hands-on skills.

It has been postulated by scholars that computer based (that is, Virtual) laboratories may help solve these problems by providing a plausible substitute to traditional or physical laboratory experiments in cases where resources are not sufficient.

Virtual laboratories are essential to both the teacher and the students, providing clear guidelines and illustrations of the natural phenomena²². Virtual laboratories provide the innovative strategies that promote high-level skills, including a problem-solving skill and experimental design. They stimulate and attract the attention of student; motivate the learners and develop discussions between students, peers and teachers. Virtual laboratories offer an interactive practical learning process as it gives students a chance to work with equipment, to gather and analyse data, to prepare experimental reports, to develop their cognitive abilities.

Laboratory, equipment, apparatus and materials that are sufficient, relevant and functional to teach and learn chemistry are essential to affecting the learning outcomes of students. Having an effective and well-stocked chemistry laboratory assists not only the students but also the teachers to gain interest in learning and teaching of basic concept in experimental chemistry.

Ineffective use of laboratories, equipment and materials for teaching chemistry in secondary schools discourages many students from having interest in chemistry and when advised or force to be in science class, the learning outcome will be affected negatively. Many individual including educators do not realise that one of the reasons why many students perform poorly and below expectation in science especially in chemistry is that our schools lack modern laboratories and relevant equipment. Many students in sciences have failed to recognise that learning should consist of pleasurable

activities at the same time, teachers need to appeal to all their senses (seeing, smelling and touching).

Science equipment is an essential and significant tool needed for teaching and learning of basic concept in science especially in chemistry as it helps to promote teachers' efficiency and improve student's achievements. Chemistry laboratory, equipment, and apparatus make learning more interesting, practical, realistic, and appealing. The availability of materials in laboratories also enables both the teachers and the students to participate actively and effectively in lesson sessions, it gives room for acquisition of necessary skills and knowledge and the development of self-confidence and self-actualisation.

Equipment is the basic tool upon which the quality of education being provided to the students in various schools is determined. This equipment helps in not only simplifying learning but also in making learning practical, effective and understandable to the learners, and helping the students to maintain a flexible and interactive classroom environment. The role and importance of equipment in the teaching and learning of chemistry in our secondary schools cannot be overemphasised. However, essential chemistry equipment is often available in most schools, and this has a great and significant influence on the students' learning outcomes²³. Equipment is used significantly for practical and demonstrations in the laboratory by teachers and students.

The chemistry equipment found in school laboratories are seen to be ill-designed, outdated and old-fashioned, and are no longer suitable in teaching. The seemingly ill-constructed, substandard equipment and materials impact on the outcome of learning of students and deter accolade of students. This pitiable state of

affairs demands a new strategy in the provision, the availability, usability and the suitability of chemistry equipment in secondary schools. Teaching and learning involve teaching materials, which are important in the teaching process. Therefore, teachers should seek the materials to be used in teaching that are needed, to supplement what textbooks offer so that they can help expand concepts and interest of students in the science subjects. Whatever the well-structured a curriculum is, unless it was implemented accordingly, the purpose might not be fulfilled.¹⁴ Instructional resources should be accessible and of quality and easily amenable to improvisation to suit the needs and ambitions of the learners in teaching and learning²⁵. These claims promote the concept of equipping teaching and learning in order to enhance learning outcome among students.

Lack of good laboratory and chemistry equipment in the secondary school can make the teachers spend quality time on the theoretical part since the students have no chance to observe, touch, smell and perform other practical tasks in chemistry. The learners cannot perform well as expected when the required instructional materials are not available. This means that the established goal of science education cannot be achieved in cases where learners are not performing, and the more the reason as to why the focus in the implementation of the curriculum requires sufficient instructional resources at the school levels.

The favourable learning outcome is likely to focus on the level of sufficiency of laboratory equipment and materials in secondary schools and effectiveness of teachers in the use of science laboratory with the objective of supporting and offering valuable learning experiences. The common assumption is that through continuous practice, one becomes good at what the learners are being taught during the classroom instructions, therefore, the dictum practice makes perfect. This may result in the

anticipation that, the chemistry laboratory equipments must be sufficiently supplied to secondary schools to be able to teach and learn chemistry effectively, this involves the provision of the schools with modern laboratory, materials and equipment, safety kits and instructional material where the acquired materials have expired.

The deplorable state of laboratory in secondary schools today is of great concern to educators. Those available seems not to be of standard quality, and some were not usable due to a lack of maintenance culture, while some are in dilapidated conditions. The laboratory has been given a central and distinct role in science education, and science educators have suggested that rich benefits in learning science accumulate from using laboratory activities. Students in secondary schools are not really interested in the theoretical aspect of chemistry, and some students have developed a negative attitude towards the subject because they are of the opinion that chemistry is abstract and difficult to learn without the necessary material and equipment needed to facilitate better understanding of the topic under discussion. Therefore, for effective teaching and learning of experimental chemistry, a well-structured, equipped, and functional laboratory needs to be put in place. However, the nature and condition of most laboratories in today's secondary schools may not likely motivate and improve students' interest in learning basic scientific concepts²⁶.

Chemistry laboratories' strategies are important in the teaching and learning of science; they directly influence/affect the results of research and experiments. Chemistry is a subdiscipline of science that deals with the study of matter and the substances that constitute it. Equipment for chemistry laboratories must be of high quality and professional to achieve the purpose of the experiment. The oldest distributors of laboratory equipment hold a wide range of new and re-approved models of chemistry laboratory instruments to meet the various research application

requirements of large and small chemistry laboratories. New devices come with the latest technology to ensure speed, accuracy, and efficiency. Furthermore, since these devices are offered for sale after rigorous quality testing, they will not have any technical defects or inaccuracies in performance.

To uphold this menace that pervades efficient instruction and learning of chemistry in our different schools, operation research done on all secondary schools indicated in its results nothing less than 10 percent of the all-secondary schools in Nigeria are equipped with laboratories²⁷. In addition, the majority of the chemistry and even science laboratories are vacant and equipment are rarely brought or acquired by the concerned stakeholders in the sphere of Education and it is not uncommon that secondary school teachers run around one school to another during external examination like West Africa Examination Council (WAEC) and the National Examination Council (NECO) to find equipment, chemicals and material to perform laboratory work²⁸. The character and state of chemistry laboratory can be a difference maker on how students can be motivated to attain their set objectives. The physical aspect of the laboratory facilities, space, lighting, ventilating, workbench, and stool affect the safety and comfort of the students and their perspective towards the concepts of Volumetric analysis in chemistry²⁹.

Chemistry is an essential subject for schools because it helps students grasp difficult scientific concepts and advances technology in all societies. Concerns about students' academic Achievement in Chemistry have been raised by educators and stakeholders in Nigeria. This issue arises from the discrepancy that has been noted between students' potential and actual achievement in Chemistry, as this has led to the necessity of doing a thorough analysis of the variables affecting this academic result³⁰.

The use of improvised and virtual teaching techniques has grown in popularity as a critical factor in determining student engagement and academic achievement. Improvised and virtual teaching strategies can significantly enhance students' interest and participation in Chemistry, thereby improving their academic performance³¹. These are critical strategies in a subject like Chemistry, where learning difficult concepts demands not just position but the understanding of numerous experimental activities that is practicable in chemistry³².

Additionally, adequate and readily available laboratory facilities are essential for the teaching and learning of chemistry. Students can conduct practical experiments in laboratories, which is an essential part of learning theoretical ideas and honing scientific abilities. The effectiveness of laboratory-based learning is directly linked to the availability of well-equipped and functional laboratories, which facilitate experimental learning and enhance students' comprehension of abstract Chemistry phenomena³³.

An important field of research is the relationship between the availability of laboratory facilities and virtual teaching strategies, especially in relation to how these elements together affect students' academic success in Chemistry. The effect of these variables, when motivational teaching is coupled with adequate laboratory resources, is that students are more likely to achieve higher academic outcomes³⁴. However, the study aims to contribute to the larger objectives of scientific literacy and technological development in the area by investigating these relationships and offering insights into how educational practices and resource allocation can be optimised to improve students' academic achievements in Chemistry.

As accepted throughout the world, the idea of using student-centred constructivist-based instructional methods is widely accepted, since teacher-centred or traditional instructional methods have given insufficient opportunities for student to construct their own learning. Eliciting students' individual capabilities, intelligence, and creative thinking can only be achieved through student-centred instructional methods³⁵. Although constructivism is a learning theory that describes the process of knowledge construction, it is the application of what are often referred to as constructivist practices in the classroom and elsewhere that provides support for the active knowledge-construction process³⁶. Since most of the contents of science lessons are abstract in nature, to help students understand such topics, it is necessary to use constructivist-based student-centred instructional methods. The concept of "learning by doing" is certainly not new; however, allowing the student to learn by doing within the classroom context is a departure from traditional methods³⁷.

In this context, laboratories are important components of educational activities in order for students to gain experience. Especially when thinking that chemistry is totally an applied branch of science, the importance of laboratory applications in instruction is clearly understood. In the chemistry laboratory, students become active in their learning by seeing, observing, and doing. Such kinds of application cause not only better but also permanent learning³⁸.

Although laboratory application in students' learning has a very important place in science education, it has some limits and problems, especially in developing countries. Some of the main problems faced in Nigeria can be summarised as follows: In carrying out experiments and arranging equipment, the laboratory activities are expensive for planning and application; it is time-consuming. Checking students' performance during the activities can be difficult in overcrowded classes. Lack of

laboratory or equipment, or insufficient laboratory conditions, which limit the teacher's ability to perform a simple laboratory activity, among others. As mentioned above, in the real-world situation, sometimes due to the limitation of equipment, limited time allocated for the topic, or insufficient laboratory conditions, teachers are forced to perform laboratory activities in crowded groups, or sometimes during harsh weather when the students can no longer assimilate. This application is opposed to the basic constructivist philosophy of laboratory method, which accepts that knowledge can be gained through personal experience and observation. When taking these limitations into consideration, looking for appropriate alternatives is inevitable. Among these alternatives, the use of educational technologies, more specifically the use of computers in supporting the laboratory methods, can be a logical one³⁹.

Many researchers and educational practitioners believe that Virtual Reality (VR) technology has provided a new insight to support education. Educational technology practices should indeed be couched in the constructivist paradigm. This plays out in terms of developing systems that are situated in the real world as much as possible and are as experimental as possible ⁴⁰. Virtual laboratory capability to facilitate constructivist-learning activities is one of its key advantages. Therefore, as an experiential learning tool, virtual reality is an active knowledge-creation and interactive learning environment by using animations and simulations for abstract topics, where students become active in their learning and provide opportunities for students to construct and understand difficult concepts more easily⁴¹. In this content, appropriate simulations and applications based on simulations generally increase learning speed by allowing students to express their real reactions easily ⁴². Better-designed simulations provide students opportunities to express their cognitive style

and to choose from the computer screen. Such opportunities allow students to develop their own hypotheses about the topic and develop their own problem-solving methods.

Technology simplifies complex information provided to the students and gives them a chance to learn through doing ⁴³. Thus, the application of virtual reality within the laboratories, that is, application of virtual laboratory or simulation programmes, solves some of the issues encountered in the traditional application of laboratories, and produces positive effects to the achievement of goals of an educational system. Eliminating errors that arise due to unfavourable laboratory conditions or improper use of the laboratory can be achieved by use of simulation programmes. Besides, it is also possible to discuss students overcoming the potential hazards which can be observed in the actual conditions of the laboratory⁴⁴. As an example, a hazardous experiment on human health is made ready on the computer in the form of simulations, in order that students can view the design of the experiment, and carry out the experiment on a computer and view the outcome. Other than the risky, challenging, or infeasible experiment, simulations possess the time, safety, cost and motivation perspectives.

Settings of laboratory facilities are meant for conducting analyses, doing scientific research, and developing. Their distinctive features, which connect research or educational activities to a particular subject or set of disciplines, are usually a specialised room arrangement or special-purpose equipment, as individuals or groups may engage in these activities, and supervision may or may not be provided. Laboratory facilities are materials or resources that can be used to ease, encourage, improve, and promote teaching and learning activities in the laboratory⁴⁵. In order to impart knowledge to the students, a scientist (teacher) employs these tools or resources judiciously. To improve comprehension of ideas, abilities, and competencies

in the teaching-learning process, laboratories offer a variety of educational resources that both educators and students may utilise in order to help students acquire concepts and information. These facilities use explicit communication. However, the tools for active learning and assessment are laboratory facilities and materials in educational classes.

An instructional material might be anything that a teacher utilises to support teaching and learning. Hence, well-equipped classrooms facilitate solid science comprehension. Laboratory has been conceptualised as a room or a building specially built for teaching practical terms⁴⁶. Using laboratory facilities to teach science and other related topics has the impact of "seeing is believing," as students tend to retain and understand what they see rather than what they are told or hear ⁴⁶. Through laboratory facilities, schools can impact their students' commitment to all science activities and academic accomplishment. Furthermore, inadequate laboratory facilities in schools can make it more difficult for instructors and students to perceive a clear emphasis on academic goals and the learning environment. As a result, these schools are less likely to be favourable to learning. The success of any scientific course greatly depends on the laboratory facilities provided for it, as the laboratory facilities are vital to the teaching of science. The creation of critical abilities and skills, such as the ability to formulate scientific questions, design studies, create scientific interpretations, and present persuasive scientific arguments, is facilitated by laboratory facilities. Laboratory facilities in science education serve as a cornerstone, offering students invaluable practical and visual learning experiences that stimulate creativity, ignite a passion for research, and instil a profound connection with nature and the environment⁴⁷.

The laboratory work contributes to developing an understanding of the essentials of the nature of science, enhancing intellectual and conceptual growth and more specifically, acquiring a positive attitude towards science, and chemistry in particular. The laboratory work is significant element in the development of some problem solving skill and application of chemistry curriculum particularly and the concept of Volumetric analysis which is based on routine-practical and laboratory work should be taught under tutelage of practical and activity- based teaching which can be practically achieved by use of equipment that is available in the laboratory, the unavailable equipment to make teaching process effective and also to strengthen the outcome in students learning³².

Poor learning outcomes of students in chemistry class might be due to the failure of teachers to conduct laboratory activities in such a way that will encourage the students to actively participate in the teaching and learning of volumetric analysis. Teachers in various schools can decide to pile up the laboratory activities in their scheme of work for weeks without teaching the students until some days before their examination, which in turn affects negatively the outcome of their examination. In addition, the school timetable is designed in such a way that the teachers will have limited time to take the students for laboratory activities of the concept they have been taught theoretically. Also, poor remuneration in terms of salary contributes in no small measure to teachers' negligence to work especially when it comes to practical sessions where their lives are exposed to hazardous chemicals, and this in turn also affect the students' learning outcome in internal examination and external examination, where students perform below expectation on yearly basis⁴⁸.

Poor learning outcomes in chemistry may also likely be a result of the unavailability, inadequacy, obsolescence, and underutilisation of laboratories and

science equipment. The underutilisation of this equipment depends largely on the type of equipment available in the laboratory and the resourcefulness of the teacher(s). If the teaching and learning of basic science will result in better student learning outcomes, consistent utilisation of science equipment should not be underestimated. Basic science in the junior secondary category is the foundation upon which science subjects (Chemistry, Physics, and Biology) are built, and as such, for a better teaching and learning process of chemistry at the senior secondary level, the students should have been well equipped from the junior level. However, poor learning outcomes in Chemistry can be linked to the utilisation and adequacy of teaching and learning resources. The inadequacy of a physical laboratory and material resources in schools may likely be responsible for poor learning outcomes of students. Schools that do not have adequate facilities, such as workshops, laboratories, classroom, and teaching/learning materials, are unlikely to produce good results in both internal and external examinations, such as the West Africa Examination Council (WAEC) and the National Examination Council (NECO).

The approaches and practices teachers use to develop students' interest, involvement, and dedication to learning are referred to as teaching strategies in education. The goal of these strategies is to affect students' intrinsic and extrinsic motivation, two factors that are vital for scholastic achievement. Students who are motivated by their own genuine interest in the material and the joy they gain from grasping new ideas are said to be intrinsically motivated. In contrast, extrinsic motivation is derived from outside sources like accolades, scores, or social acceptance. However, the way that students approach learning and perform academically as a whole is greatly influenced by both forms of motivation. Teaching strategies have a major influence on students' learning results, according to research. Motivational

strategies such as goal-setting, positive reinforcement, and the use of challenging yet achievable tasks can enhance students' self-efficacy, leading to increased persistence and effort in academic tasks⁴⁸. With the use of these strategies, students may cultivate a growth mindset in which they see setbacks as chances for progress rather than as barriers to achievement.

Mentoring entails coaching, supervising and guiding the teachers in the school as it plays an important role not only in the case of support for the development of teachers' professional skills but also in enhancing the students' performance⁴⁸. Using feedback is one of the most successful motivational techniques. Timely and constructive feedback helps students recognise their progress, understand areas that need improvement, and maintain motivation to achieve their academic goals⁴⁸. Students who get feedback that is detailed and centres around the process rather than the result are more likely to adopt a mastery-oriented approach, which has been associated with greater academic success levels. The establishment of a positive and stimulating learning environment is a crucial component of motivational techniques. Students' motivation to study can be increased by teachers who help them feel like they belong and support teamwork. When students feel supported and valued within the classroom, they are ready to give their very best towards achieving positive learning outcome.

It has also been shown that including a variety of engaging teaching strategies, such as improvised laboratory materials and virtual laboratory strategies, can boost students' motivation by giving their education greater significance and relevance. These methods allow students to connect their learning to real-world contexts, thereby increasing their interest and investment in the subject matter⁴⁹.

1.2 Statement of the Problem

Chemistry achievement over the years, especially in the area of practical activities (qualitative and quantitative analysis) in both the West Africa Examination Council and the National Examination Council, is becoming a concern to stakeholder. One such report of chief examiner was the categorical statement on the noticeable student's low performance in Volumetric Analysis. Inadequate provision of laboratory and science equipment may have contributed to Chemistry students' poor academic achievement in volumetric analysis. In order to improve students' achievement of chemistry in secondary schools and the participation and involvement of Chemistry teachers to effectively teach the basic concepts in chemistry, this study deems it necessary to explore the effectiveness of the use of improvised and virtual laboratory learning strategies to ameliorate students' challenges in Volumetric Analysis. It is against this background that this study determined the effects of improvised and Virtual laboratory teaching strategies on the academic achievement of senior secondary Chemistry students in Volumetric Analysis. The study also considers the effects of gender as a moderator variable.

1.3. Aim and Objectives of the Study

This research determined the effects of two modes of laboratory teaching strategy on the achievement of Senior Secondary Chemistry Students in Volumetric Analysis in Ondo state, Nigeria

The specific objectives of this study were to:

- i. determine the main effect of treatment on the achievement of senior secondary Chemistry Students in Volumetric Analysis;

- ii. examine the main effect of gender on the achievement of senior secondary Chemistry Students in Volumetric Analysis; and
- iii. examine the interaction effect of treatment and gender on the Achievement of senior secondary Chemistry Students in Volumetric Analysis.

1.4. Hypotheses

For this study, the following hypotheses were formulated at a 0.05 level of significance.

Ho1: There will be no significant main effect of treatment on the Achievement of senior secondary Chemistry Students in Volumetric Analysis.

Ho2: There will be no significant main effect of gender on the Achievement of senior secondary Chemistry Students in Volumetric Analysis.

Ho3: There will be no significant interaction effects of treatment and gender on the Achievement of senior secondary Chemistry Students in Volumetric Analysis.

1.5. Significance of the study

This study would be useful to the teachers, curriculum planners, Ministry of Education and the society in which the study is carried out, with the growing awareness of the importance of education to the advancement of the nation, both socially, politically, and technologically. It then becomes clear that the need for a good and scientifically based education cannot be overemphasised, since the nation has now realised the need for quality education and not quantitative, which will lead to a self-reliant nation. It is therefore significant to determine the influence of physical and virtual laboratory instructional strategies on the academic achievement of secondary school students in chemistry.

The outcome of this study would help chemistry teachers in choosing appropriate chemistry equipment or material capable of reducing students' tension and fear towards the subject and thus improving students learning outcomes in chemistry. It also motivates chemistry teachers to develop an interest in utilising suitable science equipment that will be a possible means towards reducing failure in the teaching and learning of experimental chemistry. Findings of this study also help to clarify among the teachers the need for continuous and regular improvisation of suitable chemistry equipment necessary for teaching and learning when the modern equipment are not readily available.

In addition, the findings of this research work prompt relevant agencies (both government and non-governmental) to organise seminars and workshops for training and retraining of science teachers, especially chemistry teachers, on the usage of chemistry laboratory, equipment, and materials. The outcome of this investigation would benefit the curriculum planners to design the curriculum in such a way that it will be compulsory for chemistry teachers to make use of designated laboratories, equipment, and materials to enhance the teaching and learning process.

Lastly, the study would benefit the society in the sense that students who pass through the effective use of chemistry laboratory equipment would be practically oriented, and likely lead to an increase in the production of knowledgeable people who will enhance technological advancement in society.

1.6. Scope of the Study

The focus of this study is on the effects of improvised laboratory materials and virtual laboratory teaching Strategies on the Achievement of Senior Secondary Chemistry Students in Volumetric Analysis in Ondo State, Nigeria. The geographical

scope of this study is 114 Senior Secondary School II Chemistry students, while the subject scope is Volumetric Analysis in Chemistry. The study considered gender as a moderator variable.

1.7. Operational Definition of Terms

The following terms are defined operationally for research study;

Achievement: In this study achievement represents students' learning outcomes, which are measured using the two laboratory teaching strategies (improvised and virtual)

Volumetric Analysis Achievement Test (VAAT): In this study, the Volumetric Analysis Achievement Test serves as an instrument used to elicit responses from the students

Laboratory: In this study, the laboratory serves as a means to evaluate the relative effectiveness of the two teaching strategies on students' Achievement in Volumetric Analysis

Improvise materials: In this study, improvised materials serve as locally made teaching equipment by the teacher with available materials to enhance teaching

Virtual Laboratory: online activities that consist of a set of experiment, simulation and video that allow students to be able to carry out experiment with ICTs tool

Gender: gender in this study represent male and female participants

Equipment: These are materials and apparatus used in facilitating the teaching and learning process in the Chemistry Laboratory in this study.

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Chapter Two

Literature Review

Related literature to the study will be reviewed under the following sub headings

2.1 Conceptual Review

2.1.1 Academic Achievement

2.1.2 Volumetric Analysis

2.1.3 Teaching strategies

2.1.3.1 Improvised Laboratory learning strategy

2.1.3.2 Virtual laboratory learning Strategy

2.2 Theoretical Review

2.2.1 Constructivist Learning Theory

2.2.2 Cognitive Load Theory

2.3 Review of Empirical Studies

2.3.1 Improvised Laboratory Strategy and Achievement in Volumetric Analysis

2.3.2 Virtual Teaching Strategy and Achievement in Volumetric Analysis

2.3.3 Gender and Achievement in Volumetric Analysis

2.4 Conceptual Model

2.5 Summary of Gaps in Literature

2.6 Endnotes

2.1. Conceptual Review

The Academic Achievement of Chemistry Students especially in the areas of experimental or practical activities over the years has become a source of worrisome to Educators, Curriculum Planners, the parents, students and Government at large. This calls for the need to examine the effect of Improvised laboratory materials and Virtual Laboratory learning Strategies on students' Academic Achievement in experimental activity such as Volumetric Analysis in order to check the strength and

weakness of these teaching strategies on students' Academic Achievement and see the need for Improvement.

Education is a highly significant human activity that assists any given society in shaping and modelling people to work efficiently in the society. The advantages of education are; enhancing the productive potential of the society, alleviating poverty by curbing its impact on the population, health and nutrition among other¹. Secondary education is a significant area of development at national and individual level. Secondary education is crucial in establishing a base of human resource in the country at higher levels than primary education.² The importance of secondary education might be one of the reasons why an appropriate instructional approach toward the study and learning of chemistry is necessary.

Quality secondary education provision is hence significant in the creation of opportunities and benefits of social and economic development. Cognitive achievement of learners is defined as one of the indicators of the quality of education being provided Academic achievement is assigned by test and examination scores or marks given by the subject teachers.³

The education system in Nigeria is examination oriented. The education standard is more likely to be measured with respect to the number of students who pass national examination. Teachers and society at large have been concerned severally about elements that affect the performance of the students in examinations particularly in science subjects. The performance of students in science subject in Nigeria has never been ideal and therefore has created a general interest in enhancing the performance of the science subjects in the public secondary schools in Nigeria. Besides the economic advantages that it is conceded that this would introduce, by

equipping the young people better to meet the numeracy requirements of the new work places, and generally increasing the level of skills among the workforce, there are social payoffs associated with opening wider access to post-school education and training opportunities, as well as strengthening of baselines to life-long learning.

2.1. 1 Chemistry academic achievement

Chemistry Education and academic achievement in Nigeria is a multifaceted issue which is as a result of so many factors, ranging from curriculum implementation and teachers' qualities to the availability of resources necessary for teaching/learning purpose and students' motivation ⁴. The academic achievement of students over the years in Chemistry has been rated below average and various factors have been identified as the possible reasons why students perform very low in both internal and external examination in Chemistry ⁵. This factor includes:

Inadequate resources: Many school in the Nigeria educational context lack the necessary facilities such as well-equipped laboratory, equipment and materials needed to carry out practical/experimental activities in Chemistry., This adversely hinders effective practical learning and experimental activities, shortage of qualified teachers and relevant laboratory attendants due to low pay and the refusal to leave in the rural areas is another factor militating against chemistry academic achievement among secondary schools students. Teachers are not motivated adequately, training, seminars and workshop are not been organised occasionally to enable chemistry teachers keep updated with the trends of events in the field of Chemistry and as such, some teachers may not effectively implement the curriculum due to inadequate mastery of the subject matter.

Social Economic factor: limited access to educational resources exacerbates disparities in Chemistry education, students lack of interest and negative attitude toward Chemistry as well as poor study habits can also affect students' academic achievement in Chemistry negatively, however, abstract nature of chemical concept, difficult understanding of chemistry language also contributes to ineffective teaching and learning of Chemistry.

2.1.2 Volumetric Analysis

Volumetric analysis also known as titration is a qualitative analytical technique use in the determination of the concentration of a substance in a solution through the accurate and precise measurement of volume. This method of analysis is used mainly because of its accuracy, simplicity and precision in chemistry laboratory activities. The major volumetric analysis involves acid- base titration where a solution of a known and stated molarity (titrant) is added to a solution of unknown molarity (analyte) until equilibrium is reached. The equilibrium point occurs when the amount of titrant added is stoichiometrically equivalent to the amount of analyte present, this procedure involves the use of an indicator to determine the end point of the reaction. Indicator is an organic acid or base which helps to determine the stage or point at which neutralisation reaction occur. Various types of titrations can be carried out in Chemistry, this includes:

Acid- Base titration: These involves a chemical reaction between an acid and a base, to form salt and water only, this type of titration can be used to produce different types of salt (acid salt, complex salt, basic salt etcetera) depending on the strength of the acid involved in the process. Common indicators in acid base titration includes methyl orange and phenolphthalein.

Redox titration: This type of reaction is applicable during oxidation and reduction reactions, indicators like starch can be used to determine the endpoint of the reaction.

Complexometric titration: This is a chemical reaction that involves the formation of complex ions, it involves using ethylene diamine tetra acetic acid as the titrant in the determination of concentration of metal.

Calculations: During acid base titration, calculation is a key aspect in analysing the outcome of the practical activities, the concentration of the analyte can be calculated using the formula $C_a V_a = C_b V_b$ which indicates the concentrations and the volume of reactants used. The procedure involves the preparation of the standardised titrant and analyte solution, the concentration of the titrant usually an acid should be known while that of the analyte remain unknown and should be determine. The procedure involves preparation of the reactants, setting up the parameters, addition of indicator, titration, record measurements and calculations.

Volumetric analysis is a fundamental and important technique in analytical chemistry necessary and suitable for many applications including quality control in industries, environmental testing and academic research. Chemistry students need to understand and master volumetric technique during qualitative analysis.

Chemistry is an important science subject in Nigerian secondary schools because it serves as a yardstick for higher educational learning. However, students' achievement in Chemistry calls for concern, the Chief Examiners report in West African Examination Council indicates inconsistent credits percentages in recent years. Chemistry education is vital and important for preparing scientist, technologist and skilled professionals that are essentially needed for national growth and development,

Chemistry plays an important role in industrialisation, health care provision and technological innovations. Others factors militating against students' academic achievement in Chemistry includes teachers' qualities, students' motivation, poor learning environment and class size. To ensure effective teaching and learning of various concepts in Chemistry especially experimental aspect, strategies such as curriculum reform, training and retraining of teachers, provision of resources by government, communities, educational stakeholder's and non-governmental agencies will go a long way at improving the academic achievement of students in Chemistry.

2.1.3 Teaching strategies

Teaching strategies encompass the various methods, techniques, and approaches that educators use to facilitate learning and improve students' academic achievement. Effective teaching strategies are critical to fostering understanding, critical thinking, and skill acquisition in diverse educational contexts. The choice of strategy often depends on factors such as subject matter, learning objectives, student characteristics, and available resources, with the goal of enhancing engagement and supporting learners' cognitive development⁶. Contemporary education research suggests that a strategic approach to teaching, which considers both the learning environment and individual learning needs, leads to improved educational outcomes and better prepares students for real-world problem-solving⁷.

Over the years, numerous teaching strategies have been developed and tested to address different types of learners and subject-specific challenges. Conventional teaching strategies, such as lectures and direct instruction, focus on delivering information in a structured manner and are especially useful for large groups or foundational knowledge delivery⁸. However, as educational theories have evolved,

more interactive and learner-centred strategies have gained prominence. These include inquiry-based learning, problem-based learning, team-based learning, and project-based learning, each of which emphasizes student engagement and critical thinking over rote memorization⁹.

For example, inquiry-based learning encourages students to pose questions, explore answers, and develop understanding through investigation. This approach has been particularly effective in science education, where students benefit from actively constructing knowledge rather than passively receiving information¹⁰. Similarly, problem-based learning (PBL) focuses on real-world applications and critical problem-solving skills, which are essential in subjects like chemistry¹¹. Studies indicate that students exposed to problem-based learning and inquiry-based learning strategies tend to perform better in assessments requiring application and analysis, underscoring the role of interactive teaching strategies in fostering deeper learning¹².

One emerging focus in teaching strategy research is the integration of technology, particularly Virtual learning and digital simulation, which cater to diverse learning preferences and allow for more interactive and engaging learning experiences. Virtual strategy enhances learning by providing multiple representations of information, such as images, videos, and animations, making abstract concepts more accessible and understandable¹³. Moreover, digital simulations offer interactive environments where students can experiment, make decisions, and see immediate outcomes, facilitating active learning and exploration of complex scientific processes¹⁴.

Virtual teaching strategies have become increasingly popular in fields that require hands-on practice, such as Chemistry, engineering, and medicine. Simulation allows students to learn in risk-free environments, practicing skills and applying knowledge without the consequences associated with real-life scenarios. Research

shows that simulation improves both knowledge retention and skill proficiency, as it requires students to actively engage and make decisions within the simulated context.

Teaching strategies are also evolving to address diverse learner needs and promote inclusivity. Differentiated instruction, for instance, is a strategy that tailors teaching methods and materials to accommodate varied learning styles, abilities, and interests within a single classroom¹⁵. Differentiation may include providing various levels of reading materials, using a mix of individual and group work, and offering choices in assignments, which together enhance engagement and accessibility. This approach aligns with the Universal Design for Learning (UDL) framework, which emphasizes creating flexible learning environments that can accommodate all learners and remove barriers to academic success¹⁶.

Moreover, cooperative learning, which involves students working in small groups to achieve shared learning goals, has proven effective in promoting both academic achievement and social skills¹⁷. This strategy encourages peer-to-peer interaction, fostering communication, collaboration, and empathy among students. Research indicates that cooperative learning is particularly beneficial in subjects where discussion and idea exchange enhance understanding, such as Chemistry and social sciences¹⁸. In the context of this study, examining improvised and virtual learning strategies in Chemistry education highlights how these strategies can enhance students understanding of volumetric concepts.

Teaching Conditions for Learning from Laboratory Activities Theories and research suggested that meaningful learning is possible in laboratory activities if all students are provided with opportunities to manipulate equipment and materials while working cooperatively with peers in an environment in which they are free to pursue solutions to problems that interest them. For students to acquire the manual and mental

skills associated with learning science related subject especially Chemistry, it is essential that they be fully engaged in laboratory activities. This requires sufficient improvised materials, apparatus, equipment and laboratory stations for activity groups containing not more than ten students.

The number of students in a laboratory station must be small enough for the teacher to supervise the student's activities effectively and having sufficient time to actively work with each laboratory activity group. students and teachers must have equal access to laboratory activities under appropriate supervision for all students, with provision made for adapting activities for students with special need (those with disability). Although excellent chemistry learning can take place using the simplest equipment and improvised laboratory materials, Computers and measuring instruments can be incorporated into modern teaching which can be a powerful tool for learning chemistry Virtually. However, the use of Computer should not replace laboratory practices and experience, but can be useful in data analysis and evaluation but importantly used when the physical laboratory is not available due to reasons beyond teachers' control.

Evaluation of student learning in chemistry should include assessment of skills developed in laboratory activities as well as the knowledge acquired during these activities. Test questions relating directly to laboratory work should not only to address laboratory learning, but also communicate the importance of laboratory work to students. To enhance effective laboratory activities, it is expected that teachers, technologists and instructors, have adequate and convenient storage facilities that can provide first hand access to apparatus, equipment and materials through cataloguing.

Safe laboratory work for students and teachers requires adequate, up-to-date safety equipment; an emphasis on safe practice in all activities; and the availability of resources and references on safety, retraining courses to laboratory personnel to maintain their skills and keep abreast of new developments in chemistry teaching, teachers need time, money, support, and encouragement to participate in appropriate professional activities. These may include attendance at workshops and professional conferences; examining new laboratory equipment, curricula, texts and resource materials; and working and consulting with colleagues in schools and colleges and in the chemistry and science research community.

Relevance of Laboratory Experiment in the Teaching of Laboratory tasks help the students to develop a broad array of basic skills and tools of experimental chemistry and data analysis. While it is imperative that students have a broad experience with techniques using laboratory equipment, it is impossible to prescribe precisely which equipment should be used in all chemistry laboratories. At the same time, it is advisable to allow students to make the use of many different types of laboratory apparatus to make observations. The laboratory should help students master basic chemistry concepts (qualitatively and quantitatively). A growing body of research in chemistry education indicates that a majority of students have difficulty in learning basic experimental concepts in a course built around conventional teaching methods, textbook problems, and verification of experiments.

To improve learning, students must actively confront difficult concepts. Effective learning may also be assisted by close interaction of students with their peers in this process. The laboratory can be an excellent environment for active learning. The laboratory has long been considered useful to develop conceptual understanding, but some recent courses have been developed that rely heavily on laboratory

experience, in contrast to conventional teaching methods, for the development of conceptual understanding of chemistry. The Role of improvised materials in science Laboratory Teaching the Case of chemistry, conceptually oriented laboratory experiences may constitute a portion of the laboratory program, the entire laboratory program, or the entire course. The laboratory should help students understand the role of direct observation in chemistry and to distinguish between inferences based on theory and the outcomes of experiments. chemistry is a complex structure of concepts, hypotheses, theories, and observations that are interrelated in such a way that it is often difficult to separate inferences based on theory from direct observations based on laboratory experiments. The basis of knowledge of the laws of chemistry and that chemistry is not merely a collection of equations and textbook problems. The most important feature of effective chemistry teaching is to support theoretical explanations with actual practices in the laboratory¹⁸.

The laboratory practices generally aim to improve the students' abilities by providing observation for conducting the experiments. Laboratory activities have long had a distinctive and central role in chemistry curriculum, and chemistry educators have suggested that many benefits accrued from engaging students in chemistry laboratory activities. Also, the use of inquiry approaches in College Chemistry Laboratory courses provide evidence that such approaches involve students more and more inductive than traditional approaches. The approaches provide less direction and therefore assign students more responsibility to determine procedural strategies and encourage students to make more use of chemistry¹⁸

Gender-sensitive teaching strategies have also garnered attention, recognizing that students may experience and respond to instructional methods differently based on gender. Studies suggest that certain teaching strategies, such as interactive learning

and visual aids, may be particularly beneficial for female students in traditionally male-dominated subjects like Science, Technology, Engineering, and Mathematics (STEM)¹⁹. In this study's context, understanding how improvised and virtual strategies affect male and female students differently can contribute to developing inclusive teaching approaches that address gender-based learning preferences and promote equal learning opportunities.

Finally, research underscores the importance of teaching strategies that enable teachers to respond to classroom dynamics and students' evolving needs. Adaptive teaching is a responsive approach that involves modifying instructional methods based on real-time assessment of student understanding²⁰. Teachers who use adaptive strategies may adjust lesson pacing, revisit complex topics, or incorporate additional resources to support students who may be struggling. Adaptive teaching strategies align with formative assessment, a process where educators use ongoing feedback to guide instruction and improve learning outcomes, thereby supporting both struggling students and those who excel²¹.

Teaching strategies have evolved from teacher-centred to student-centred approaches, emphasizing interactivity, technology integration, and inclusivity. By understanding and implementing effective teaching strategies, educators can significantly enhance student learning outcomes, particularly in challenging subjects like volumetric analysis. This study's focus on improvised and virtual strategies, with consideration for gender differences, contributes to the growing body of knowledge on inclusive instructional practices in science education, offering insights that can benefit both educators and students in achieving higher academic performance.

2.1.2.1 Improvised laboratory

To ensure a healthy academic performance in the schools there exists the necessity to provide essential infrastructures that include; Science laboratory, school library, classes, storage facilities and other forms of solid waste disposal among others. Science lab is significant to scientific training in which theoretical study is put into practice. Practical in any learning experiences entails the students engaging in such activities as observing, counting, measuring, experimenting and recording²³. Regardless of whether it is a well-equipped or improvised science laboratory, without it, one cannot effectively conduct the science teaching process in any school or other educational institution.

Among the instruments through which the procedure of experimental activities can be tilted is the laboratory through which the student undergoes the process of inquiry hence the study in a laboratory is a key and fundamental component of science subjects. Science laboratory work is a practical exercise that focuses on process and motor skills that aid the scientists to discover solutions to problems and boost the study of science²⁴. The interest of learners is aroused by laboratory activities because they are supposed to participate in valuable scientific activities and experiments individually and collectively. This gives the learners the rudimentary skills and scientific means of problem solving.

It is highly desirable that students should touch and feel materials and equipment in learning science by experiment; which not only will help students to master process, learn new knowledge about science, but also scientific attitude, including honesty, open-mindedness, and cooperation as moralities of science, and improve and strengthen the understanding and memorization of hard ideas and procedures²⁵. Lab facilities provide students with a slight idea of scientific theory and

leave them with the sense of the science reality that subsequently enhances their academic performance in examinations.

Equipment improvisation in teaching science as it can be applied to Chemistry is a move to embrace and utilize local resources in teaching/learning of the abstract experimental concept in Chemistry in case the ready-made equipment is not easily accessible, in temporary or inaccessible to the users. This improvised content may be done by the teacher or the students. Improvisation as applied to science may be described as the process of finding alternative resources with which to enrich the teaching of science where actual resources are not available or are in short supply. The teacher initiates the production of the alternative resources and the production ends up in his hands or with the local craftsman (Example, carpenter, blacksmith, welder etc).

It evolved slowly out of the serviceable social occupation in the history of the race of science. Physics grew gradually as the use of tools and machine, which are present in the context of seeking ways of achieving practical ends. Chemistry too developed out of the procedure of tinging, bleaching and metal work ²⁶. It is thus realised with the above illustrations that science is nothing more than creativity and the harnessing of material and resources within and around our surroundings, to address the man's problem of limitless wants. This will lower our excessive reliance on the imported technology that have ultimately managed to support the lives of the people but have not really done much to educate the people.

Non-available laboratory equipment in schools needs to be improvised so that first-hand information can be received and the scientific abilities as the objectives set can be gained. Without the interaction of students and the environmental resources (material and equipment), teaching of Chemistry cannot be done effectively. A

curriculum of science is also designed to allow the teacher to teach through activity oriented and child centred approach (guided enquiry). But research evidence indicates that, either laboratory equipment, teaching and learning apparatus and material are either inadequate or simply non-existent in schools to such a level that most teachers are left to verbal exposition of scientific principles, facts and concept²⁷. The verbal presentation fails to facilitate the acquisition of skills, the development of skills, objectivity and critical capabilities that will facilitate the child to operate successfully in the society. It is due to this that the necessity to have other sources of teaching materials and equipment becomes inevitable. A rich source of such materials is given by the school environment and homes of students and a resourceful teacher can himself or with the help of students and other members of the society improvise laboratory material to purpose of teaching and learning. It has been long promoted to use improvised laboratory instructional materials to teach science.

Educators (teachers) have to ensure they make improvements in teaching aids and materials to the teaching and learning process. In one scenario, such as when there is insufficient or complete lack of a standard and universally acceptable material or equipment and the unavailability of virtual laboratory to teach science in the case of teaching science, the students with the aid of the teachers will have to produce teaching aids locally, a substitute of the usual materials which will assist in the effective teaching and learning of science. This will help to develop creativity and spirit of resourcefulness among the teachers and the students.

The success of students in chemistry can be achieved provided that there is sufficient focus on the production and delivery of teaching resources in our laboratories because this will guarantee the development of creativity and scientific expertise in the teachers and students. Similarly, improvisation requires adventure,

creativity, curiosity and perseverance in the case of the teachers, these qualities can be realised only with an effective training programme on improvisation²⁸. Improvisation at the level of creativity was substitution and construction. Substitution in improvisation merely refers to the methods by which the already prepared local material is employed in place of a piece of equipment, which is unavailable, whereas construction is the process of making or fabricating a new equipment to be used in the laboratory instead of the unavailable original one where substitution cannot be made. Cognitive bridge between abstract and real teaching and learning experience of students is also offered by improvisation strategy. With its creative capacity and imagination, the students are engaged in production of improvised laboratory equipment or materials, it provides new ideas of the things that lie beyond the scope of ordinary experience to the students and permanent. In order that a student can improvise, he/she must be innovative, resourceful and creative in both his/her thinking and manipulative abilities ²⁹.

Laboratory material and equipment improvisation can be used as an option to unavailable, fragile, expensive and broken equipment. It is a means of expanding inquiry, curiosity, creativity, productivity and intellectual capacities of students. It is also the way of local utilization of the universality of science, it minimizes the inadmissible and poor attitude of some teachers who discard experimental topics (qualitative and quantitative) because teaching materials are not available. Learning is less instructive, practicable and enduring when improvised laboratory materials are used ³⁰.

Big or small materials may equally be made available in the laboratory via improvisation process. Dangerous original or real materials may be improvised¹⁴. Improvisation is also useful in addressing the issues of supplying materials to all the

students. It assists in the supplementation of verbal description and elucidation by observable and or touchable and objects that may be manipulated objects³¹.

Moreover, improvisation is an act of a versatile science teacher that allows him to employ the use of substitutes to costly and unavailable supplies in the process of teaching in a laboratory. It also assists in bridging the gap between the abstract to reality to students, it also assists in filling the vacuum existing or otherwise existing in the teaching learning process. Improvisation of science teaching aids/materials involve a few issues this has both technical and human factors. Certain technical aspects question the measure of accuracy and precision that is possible with improvised laboratory materials and equipment compared to the already produced or factory-produced one. This issue is more critical at the secondary and tertiary level where higher sensitivity experiment and observations are conducted. Other technical problem concerns the issues of use. Issues related to the professional engagements of the teachers, their creativity and technical prowess, ingenuity and competence are the human factors. The answer to this is whether a teacher will skip all work in laboratories or work in practice in case ready-made materials are not presented? Is he able to conceive satisfactory alternatives to at least some of the apparatus? Will he consider the laboratory instructional consequences (degree of required accuracy) and, in particular, range of possible alternative and costs³².

Improvisation of Chemistry laboratory materials is a form of enquiry widening or a challenge to curiosity, creativity and productive application intellects and sees it as the aid or production of similar or near similar instructional materials to aid in learning and to enhance the outcome of learning. A high degree of variation will most probably exist between the students being taught with improvised lab instructional material and the students being taught with the Conventional means.

This interest in increasing levels of achievement has been the focus of considering range of factors that determine achievement as well as how these factors interact in limiting and increasing achievement in various categories of students. These include the introduction of in-service training to the teachers. This paper will thus aim at trying to define how the use of improvised laboratory materials and Virtual laboratory Teaching influenced the Academic Achievement of students in Volumetric Analysis in Ondo North Senatorial District of Ondo State.

The science laboratory an isolated learning setting, is an environment where the students will be able to collaborate as a small group to explore scientific phenomena and discovery. A laboratory is a structure or a room, with equipment, that is used and prepared to carry out practical or experimental work; a laboratory is the core of good scientific programme that enables students in the school to experience which are consistence with the aim of scientific literacy. This means that teaching and learning science cannot be fully done in secondary school where the laboratory is not well equipped. The laboratory activities involve experiment, observation, conclusion or inferences among other activities and the activities assist the students in mastering the scientific skills.

Laboratory may be indoor like the adequately improvised, equipped and designed room available in most schools. Regardless of the kind of laboratory used in the teaching of science, it is expected that the same laboratory experience is achieved, that the involvement in the series of experimental, observational, and demonstrational activities gave the opportunity to the students to gain the knowledge of practical and theoretical concept by solving problems³³.

The school cannot do without laboratory as a condition that successful teaching and learning of science subjects can be realized. Whatever one does in the science laboratory, however, is to learn skills that will assist in advancing the science knowledge which in turn will aid in the building up of human, society and also make much contribution to the nation building and sustainability. In comparison with the traditional classroom environments, laboratory would be less formal and offer more chances to engage students and their teachers. This increased interaction will, most likely, foster more positive social interactions that are best suited to facilitating a positive and constructive learning environment.

Among the many advantages of using improvised science laboratory in teaching and learning of basic topic particularly in Volumetric analysis is the employment of Laboratory studies in instilling the students or learners to learn the nature of science and technology in order to promote the knowledge of human enterprise of science and thereby help the child intellectual and aesthetic knowledge of the child³³. Capability of Students to be taught to value and in fact imitate the position of the scientist by means of learning to use the manipulative skills, by growing an interest, attitude and values by evaluating what science entails, it is evident that field experience offers the optimal prospect of generating a lifetime interest in science to students given the opportunity to have personal experience with the real objects among others. The lack of science laboratories or insufficient science equipment in science laboratories in our secondary school influences the attitude of teachers to work, as well as to the goals of science experiment³⁴. Science experiments are two unavoidable components of learning experiences. The experiments offer not only the acquisition of concepts of science but also learning experiences in terms of scientific methods.

There are eight dimensions of scientific attitude that exist and all of them can be cultivated in the science laboratories in our different schools, which includes Curiosity, Open mindedness, Objectivity, Intellectual Honesty, Rationality, Willingness to suspend judgement, Humility and Reverence to life. Since the late 19th century, science educators feel that the laboratory is a relevant instructional tool in science. Science educators argue that laboratory instruction is regarded to be essential as it trains the observation, provides more detailed information and increases interest of the student. Potential outcomes that can be met with a properly designed and highly developed laboratory programme will be: Become intuitive and build on foundations of basic scientific concepts, apply in-classroom learning to new scenario, experience basic phenomena, develop experiment and data analysis skills, learn to use scientific equipment, learn to estimate error of statistics and recognize scientific errors and Develop reporting skills (written and Oral)³⁵.

Large lecture courses are often accompanied by laboratory teaching to make sure that the students can obtain the technical skills and implement the concepts and theories offered in the lecture³⁶. Practical experience makes students think inquisitively and it enables them to obtain skills in science and the appropriate mindset to operate complex scientific instruments and corrosive reagent and chemicals and the materials necessary in carrying out the experiment. Science lab offers students the most endowed experiences that they would bring into the society as well as their workplaces. It assists in giving the students the chances to be like a scientist would. To be effective, the laboratories the students need to know not only how to carry out a specific experiment, but also why the experiment is worth carrying out. That is, in order that a student conducts a certain experiment particularly in Chemistry there must be a reason why the experiment must be conducted at that particular time. The use it

will have to serve of understanding concept, relation or process better. There are five categories of educational goals that can be attained by the application of science laboratory in science teaching and those are: Skills: (manipulative, inquiry, investigative, organisational and communicative), Concept of mastery: (Hypothesis, Theoretical model and taxonomy category), Development of cognitive abilities: (Critical thinking, problem solving application, analysis and synthesis), Understanding the nature of science (scientific enterprises, scientist and how they work, existence of multiplicity of scientific methods, inter-relationships between science and technology and between the various discipline.³⁷

Given the role of science laboratory on the learning outcome in science particularly Chemistry, this means that without laboratories where students can perform experiment in simple volumetry analysis, the result will be the production of students who will be ignorant on fundamental practical that are required by the state and federal ministry of education. Such students will therefore not have the pre-req and needed qualification to write science subjects such as Chemistry, Physics and Biology in external exams such as the West Africa Examination Council (WAEC) and the National Examination Council (NECO).

An improvised teaching laboratory is an issue of concern in the teaching of chemistry as one of the science subjects in our different secondary schools. The reason behind this is that when the students are exposed to improvised laboratory set-up quite often, they build interest in the subject and build their own interpretation of some fundamental concepts of chemistry. This knowledge cannot merely be passed on by the teacher alone, but has to be built by students during their interaction with the environment and the teacher. Laboratory activities will be well integrated with learning sequence and the resultant meaningful learning will take place. Secondary

level education also divides laboratory practice with lectures in order to improve better learning and comprehension of concepts of chemistry by the students.

Improved Laboratory Learning approach can generate much larger educational returns than Conventional learning approach, and seems to do so as well with college students of all ability not only the very academically talented, but also with the low performing among them who seem to constitute the bulk of the student³⁸. Students in an effectively planned and constructed laboratory get close interaction with teachers and other students, thereby, improving learning by favoring learning, being able to monitor and test learning³⁹. It has been identified that an effective laboratory program in chemistry, which is a stimulant in encouraging the student to study. Also, a well-designed laboratory can be a popular component of chemistry courses and can promote quality learning⁴⁰.

Laboratory exercises that are poorly designed enable students to scaffold the learning of other students. Moreover, provided a properly designed laboratory exercise, students are able to experiment and participate, individually and in groups, in open-ended laboratory and inquiry-based learning tasks which involve deriving theory into applicable and practical problems in the real-life. The objectives in the laboratories work in the teaching of chemistry has also been categorised into four, namely the fulfilment of the conceptual learning, acquisition of technical skills, acquisition of research skills, and creation of viable learning products¹⁷. Moreover, abstract concepts in chemistry can be acquired with the help of improvised laboratory experiments by the students. The students find practical work interesting and fun. Consequently, they take the initiative to read the material that are related to the issues in the classroom. The work in the laboratory promotes solving the problem and approaching it, discovering the facts and new principles and developing the ability of cooperation and

critical attitude to the subject. Nevertheless, the role of teachers in assisting the students to attain these positive objectives of practical work cannot be underestimated.

Experiments in chemistry labs play significant roles in schools by stimulating interest among the students in learning, enhancing the learning process among the students, and training them in terms of observation and thinking skills. These experiments are an elementary portion of chemistry instruction and foster the students' science and study spirit. They also give students a chance to exercise analytical skills that can be utilised in any sphere of their life, including the social aspect. Besides, the experiments of the chemistry laboratory are a certain opportunity to make students closer to science and career choice even in case they are unable to come to the research facilities directly. By using these experiments, students would be able to gain more knowledge on the basic concepts and laws of physics, build up their ability to think scientifically and be more proficient at questioning. On the whole, the importance of chemistry laboratory experiments is that they enable the development of a culture of integrated chemistry learning and equip students with the future challenges of scientific research.

The role of the teacher is to establish the positive learning conditions within the laboratory in order to realise optimal education among the low performing students. When laboratory experiences allow it, the objectives of the National Research Council on Chemistry and other science related subjects can be augmented by; pose a research question, operation of laboratory tools and procedures, make observations, assemble and analyse data, verify, test, or evaluate explanatory models (including testing known scientific theories and scientific laws). formulate alternative hypotheses, plan investigations, and construct or modify explanatory models ⁴¹. It was noted that science Laboratory Equipment refer to any special purpose instruments in the

execution of experiments. These tools contain numerous various instruments that enable students to make experiments and see how other physical processes are performed. Laboratory teaching presupposes that experience in observation and manipulation of the materials of science is better than other modes of developing, understanding and appreciation. There is also often the use of laboratory training to gain skills that will contribute to a more advanced research or study.

Theoretically, the student activity, sensorimotor character of the experience and individualization of instruction in the laboratory should have positive effects on learning. It is impossible, however, to usually get information as quickly as it can, by direct experience, out of abstractions given orally or in print. It would not therefore be supposed that laboratory teaching should have an advantage over other modes of teaching in the volume of information memorised, in capacity to use learning, or in real proficiency in observation or manipulation of materials ¹⁷. The utilisation of the laboratory in college science is misconceived. One is that laboratories somehow illustrate lecture courses - a purpose that cannot be achieved in a one-afternoon exercise. It was argued that the majority of scientific theories rely on a vast amount of highly complex experiments. should lecture subjects be exemplified, it should be by the use of audio-visual aids or demonstrations ⁴². The second fallacy is that laboratories exist to instruct manipulative skills and majority of the students in science laboratory courses do not have a career objective of being professional scientists.

Many of the skills students acquire in school laboratories are rarely applied in real scientific careers. When these skills are taught, their value lies more in equipping students with basic tools for scientific inquiry rather than being seen as goals in themselves. Several studies have highlighted the importance of laboratories in the teaching of chemistry at the secondary school level. Laboratory equipment refers to

specialized tools designed for conducting experiments, such as measuring devices, chemicals, Bunsen burners, glassware, and other apparatus essential for practical work in chemistry and related sciences like physics and biology.

Researchers have investigated the influence of laboratory experiences on various aspects, including student achievement, attitudes, critical thinking, cognitive development, scientific understanding, process and manipulative skills, interest, retention in science courses, and independent learning. However, many of these studies report “no significant differences” between students who used laboratory methods and those who did not. Decades ago, the National Science Teachers Association addressed this issue in its publication *What Research Says to the Science Teacher*, dedicating a chapter to the role of laboratories in secondary school science programs.

Although laboratory teaching may not be the most effective method for ensuring information retention, the growing demand for educational accountability has shifted focus toward raising test scores. Outcomes associated with laboratory-based learning, however, are often difficult to measure using multiple-choice tests. Nonetheless, some research findings show that laboratory activities can be particularly beneficial for students who initially perform at medium or low levels on pre-test assessments.

Improvised laboratory instruction has been shown to enhance students’ problem-solving abilities in science learning. The laboratory can serve as an effective instructional strategy, particularly when experiments are presented as real problems rather than tasks with step-by-step directions. When working with disadvantaged students, it is crucial to design laboratory activities that create a sense of cognitive

conflict or disequilibrium, as this promotes intellectual growth. In high school chemistry, laboratory activities not only expose students to scientific phenomena but also provide a foundation for systematically developing their ideas and serve as a platform to test the predictive strength of their reasoning⁴³.

2.1.2.2 Virtual Laboratory

Laboratory work is an essential component in the study of Chemistry as well as other natural science discipline like Biology, Physics and Computer science. It helps students to learn basic concepts and hands on skills as well as help students to be able to illustrate theories. Furthermore, the practical laboratory classes increase students' curiosity and positive attitudes towards science. Despite its numerous importance, physical laboratory work is still been confronted with numerous challenges such as the high cost of laboratory equipment and material as well as dangers encountered when working with highly toxic chemicals and dangerous scientific tools. However, recent findings shows that the integration of Information and Communication Technologies (ICTs) such as simulations, animations, videos and visualisation with real practical work is very promising.

A virtual laboratory can be defined as an online activity that consist of a set of experiment, simulation and videos that allows students to carry out needed experiment with the use of ICTs tools virtually which have the ability to advocate for and bring about improvement to the face-to-face practical-based learning. Students can learn basic concepts in Chemistry and gain new skills using virtual laboratory anytime from any place convenient and conducive, through the use of communication gadgets such as Laptops and smartphones. However, it is important to state that students in the virtual laboratories might make some negligible errors with minimal consequences

compared to the physical laboratory, thus improving their confidence in carrying out real work. Also, a virtual laboratory can help students to conduct some tasks in Chemistry that cannot be easily conducted in the physical laboratory due to a lack of equipment and materials needed for experimental activities. In a virtual laboratory, students can observe visual representations of natural phenomena, collect data, make predictions, and write hypotheses in order to become actively involved in the scientific process of inquiry.

Virtual laboratory provides students with the opportunity to experiment and explore concepts in a dynamic and interactive way, which will in turn, lead to a better understanding of complex scientific principles. Many virtual laboratories offer immediate feedback on experiment, which give room for students to learn immediately from their mistakes and correct their approach when working in a physical laboratory. Virtual laboratory can be structured in such a way that it will accommodate large numbers of students or participant making it ideal for institutions with limited physical laboratory equipment, this is attributed to lack of practical engagement with the subject, limited use of modern teachings aids and over reliance on traditional teaching methods.

Virtual simulations have been found to enhance students' knowledge and confidence in laboratory work by offering flexible learning opportunities ⁴⁴. Due to their importance in science education, particularly in chemistry, computer-based laboratories have been adopted globally, spanning from primary to tertiary education. Several studies have examined the role of virtual laboratories in chemistry instruction across different contexts. For example, students who engaged in virtual chemistry laboratory activities (experimental group) demonstrated higher cognitive learning outcomes compared to those taught through traditional lecture methods ⁴⁴.

However, many virtual laboratory studies have primarily emphasized overall cognitive achievement without investigating specific cognitive skills or considering how factors such as student demographics may affect their effectiveness. Research on virtual experimental platforms has also explored their impact on students' self-efficacy in chemistry but often overlooked these additional dimensions. Virtual laboratory simulations have been shown to improve senior secondary students' understanding of science process skills in practical chemistry, thereby enhancing their abilities ⁴⁵. Similarly, studies on virtual reality applications in chemistry laboratories reported positive effects on students' self-efficacy, interest, conceptual understanding, and reduced laboratory anxiety. Nonetheless, these studies did not address the long-term influence of virtual laboratories on learning achievements or students' engagement in actual laboratory environments ⁴⁶.

Although real laboratory experiments are essential for fostering cognitive, affective, and psychomotor learning domains, their full implementation in low-income countries like Nigeria is hindered by several challenges. To address these limitations, many educational sectors have turned to technology-based approaches as alternatives for teaching and learning. In recognition of the need to strengthen science education, the Nigerian government has incorporated basic science and technology into its educational policy at both the primary and junior secondary levels, preparing students for more advanced laboratory activities in senior secondary school. Consequently, a growing number of Nigerian schools are integrating technology into classroom instruction. However, despite the progress made in information and communication technology, the actual level of virtual laboratory adoption in Nigerian schools remains uncertain, especially in contexts where conventional laboratory experiments are either constrained or unavailable.

Despite various efforts by educators, curriculum planners and policy maker to reform the curriculum and teaching strategies in secondary schools, academic achievement in Chemistry over the years is unsatisfactory, particularly in schools where resources for teaching and learning of basic concepts in experimental chemistry is limited or not even available, to address this, there is a need for alternative teaching strategy that can provide students with opportunity for hands on learning and hence the need for virtual classroom session in place of physical laboratory in the teaching of various topics that are practically oriented in Chemistry.

Virtual laboratory can also be described as the use of animations to simulate the real laboratory experimentation especially in chemistry teaching where there are problems associated with the setting up of the physical laboratory due to high-cost implication and the danger associated with the handling of various tools, equipment and materials (toxic) needed for the teaching of practical concepts in Chemistry. A virtual laboratory employs computers to simulate or animate specific scientific phenomena, allowing students to engage in hands-on activities aimed at deepening their understanding of underlying principles. Essentially, it is a laboratory experience without physical walls and doors ⁴⁷. Virtual laboratories help bridge the gap between theoretical knowledge and practical application by electronically simulating real experiments. Since students require practical exposure to fully grasp abstract concepts in chemistry, laboratory activities play a vital role in strengthening mastery of scientific ideas. Where access to real laboratories is limited, adopting suitable alternatives becomes necessary. Thus, the use of virtual laboratories in conjunction with improvised laboratory methods presents a logical solution.

Virtual laboratories provide a digital environment that mimics real laboratory settings, offering learners the opportunity to develop laboratory skills. They supply

students with virtual tools, materials, and laboratory setups on a computer, enabling experiments to be conducted individually or collaboratively, anytime and anywhere. Research has shown that virtual laboratories can positively influence students' performance in chemistry, improving both achievement and attitudes toward the subject ⁴⁸.

Virtual laboratories have also been found to enhance students' achievement in other science-related subjects. For example, students taught physics practical using a virtual laboratory approach performed better than their counterparts who received instruction through conventional lecture methods ⁴⁹. This suggests that virtual science laboratory packages can improve students' performance in much the same way as improvised laboratories. Essentially, a virtual laboratory is composed mainly of computer systems programmed to simulate real laboratory experiments electronically. Its core components typically include the following:

1. Laboratory set and equipment: The virtual laboratory is designed as a complement to the traditional laboratory rather than a replacement. While physical laboratories remain essential, they can be provided in smaller numbers and with reduced requirements, making them accessible for multiple users beyond the physical laboratory setting.

2. Computer devices: These include personal computers connected either to a local network or the internet, enabling students to conduct experiments directly in the laboratory or remotely from any location at any time.

3. Communication network and related hardware: For electronic experiments to be carried out effectively, all equipment must be directly linked to computers, as interaction between the user and the laboratory occurs through digital communication.

4. Virtual laboratory programs: These consist of professionally developed simulation software. To sustain students' interest and engagement, the programs are designed to be interactive, incorporating animations, videos, and three-dimensional graphics that replicate real laboratory experiences.

5. Cooperation and management programs: These programs handle the administration of the virtual laboratory, including registering users (students and researchers), managing experiments, and assigning different levels of access depending on the user's role.

6. Technical staff: Well-trained personnel are required to manage and operate the virtual laboratory effectively in order to achieve its educational objectives.

The effectiveness of virtual laboratory and virtual experiment in science especially in Chemistry has gained considerable popularity in research. Several distinct benefits of using virtual experiment in education includes reduction in the equipment needs that are primarily important in the physical laboratory settings, they are available at all times from anywhere and they offer the students the opportunity to learn at their own pace while exploring difficult or interesting concepts. Other important benefits of virtual laboratory in the teaching and learning of sciences includes: Reduced economic and time cost, Green/eco-friendly alternative, Flexible learning environment and Safety ⁵⁰.

The potential benefits of virtual laboratory learning strategy for science teaching cannot be underestimated in the contemporary world. Virtual laboratory makes students become active in their learning, provides opportunity for student/learners to construct and understand difficult concepts more easily, furthermore, it affords the learners the skills to overcome mistakes that occur as a

result of misuse of the real laboratory and enable them to easily overcome the possible danger that can be seen in the real physical laboratory conditions. It also provides an affordable, safe, easy and ideal working environment. Furthermore, Virtual laboratory experimentation brings about better academic achievement in science. Virtual laboratory creates new intellectual model in education and more beautiful than the physical laboratory learning strategy, it builds knowledge and inculcates information, it encourages and guide students, register students' information and evaluates them automatically.

The nature of a science laboratory, particularly a chemistry laboratory, plays a significant role in shaping students' motivation and achievement of academic goals. The physical environment such as the availability of facilities, adequate space, lighting, ventilation, workbenches, and seating affects not only students' safety and comfort but also their attitudes toward the subject and overall learning experience. A well-structured laboratory environment can foster students' personal development while positively influencing teaching and learning outcomes in chemistry. Students' perceptions of their learning environment also determine the extent to which they engage with, understand, and retain knowledge.

Moreover, the condition of the laboratory building itself is an important factor in evaluating the quality of educational facilities. Research suggests that the age of school buildings may be positively correlated with student achievement, with older buildings often associated with reduced instructional effectiveness. In fact, deteriorating infrastructure can hinder both teaching and learning by causing disruptions that lead to the loss of instructional time ⁵¹.

Students who learn in modern, well-equipped laboratories tend to perform significantly better in chemistry practical compared to their peers in outdated or poorly

maintained facilities. This suggests that the persistent reports of low achievement in secondary school chemistry may be linked to two key factors: students' perceptions of their laboratory learning environment and teachers' failure to engage students as active participants in experimental chemistry. In many schools across Ondo State, the state of the laboratory likely has a direct impact—either positive or negative—on students' learning outcomes. Therefore, both the quality of the laboratory environment and the teacher's ability to actively involve students in practical work must be taken into account when addressing poor performance in chemistry.

Low achievement in chemistry is often a reflection of inadequacies within the laboratory learning environment at the school level. A review of existing studies indicates that the influence of the laboratory environment on student outcomes in secondary school science has not been widely investigated in Ondo State or even in Nigeria at large. This gap in the literature underscores the need for a comprehensive study on the role of laboratory learning environments in science education.

Laboratory activities cannot be considered complete without the necessary equipment, as students would be left with only theoretical knowledge and deprived of opportunities to apply scientific principles and theories in practice. Practical work allows students to connect content with the processes through which scientific knowledge is developed. Indeed, laboratory work provides one of the most effective means for students to experience the process of scientific inquiry firsthand.

Typically, laboratory activities begin with demonstrations of key techniques, proper handling of materials, or the operation of specialized equipment. During this stage, students gather around the teacher to observe closely and listen carefully, ensuring they understand the procedures. Teachers often emphasize essential terms

and functions to build excitement about the laboratory activity. Importantly, teachers should avoid demonstrating equipment with which they lack familiarity, as mistakes during demonstrations can hinder learning. However, if errors occur, teachers should use them as instructional opportunities by explaining how the mistake was made, thereby modeling reflective practice. Familiarity with equipment prior to demonstration is therefore critical for effective laboratory instruction.

An effective science teacher should play an active role throughout the laboratory session, maintaining a steady pace of interaction so that students clearly understand what to expect from their instructor. Key instructional points should be addressed during whole-class moments, especially when recurring questions or problems arise across groups, as these are likely shared by the entire class. At such points, the teacher can provide timely, targeted feedback or “just-in-time” instruction to all students simultaneously. During practical sessions, the teacher is expected to move around the laboratory to remain accessible, devoting equal attention to both groups that ask for help and those that remain silent. Monitoring students’ progress, calling them by name, and listening to their group discussions allows the teacher to anticipate and address instructional challenges early. Importantly, teachers should not assume that a quiet group is necessarily on track; careful observation of their actions and conversations can reveal hidden misconceptions. Approaching groups proactively and prompting them with questions such as “explain what you are doing” helps to confirm their understanding and ensures they remain engaged in the right direction ⁵².

The effective teaching, learning, and understanding of basic concepts in chemistry can only occur when theoretical explanations are reinforced with hands-on laboratory practice. Laboratory instruction remains the most effective method for training students in the skills and values of scientific investigation while also fostering

positive attitudes towards chemistry. Concepts taught in traditional classrooms, when supplemented with laboratory instructional techniques (both physical and virtual), often yield significantly better outcomes compared to conventional lecture or textbook methods.

Laboratory work is therefore an indispensable component of chemistry education, and no effective science teaching can exist without practical activities. The success of laboratory instruction, however, depends on both the adequacy of laboratory equipment and the teacher's ability to utilize them effectively. Current curricular trends emphasize the integration of laboratory activities into classroom teaching, with both pre-laboratory preparation and post-laboratory discussions serving as essential parts of the learning process ⁵³.

Despite its importance, laboratory teaching in chemistry is beset with numerous challenges. A major issue is the inadequate provision of equipment, often stemming from poor planning and resource allocation. These limitations frequently compel teachers to separate theoretical instruction from practical work, postponing hands-on laboratory activities until the second term of the students' final year, rather than embedding them throughout the learning process ⁵⁴.

Over the years, students' achievement in chemistry has remained consistently low and below expectations, a trend largely attributed to the inadequate state of laboratory facilities in secondary schools. Similar patterns of poor achievement are also evident in other science subjects such as Physics and Biology. In the case of biology, for instance, many students enroll in the subject because it is perceived as easier and is compulsory in the secondary school curriculum. Although instructional aids for biology can often be sourced locally, both teachers and students frequently

complain about the shortage of materials, particularly given the large number of learners requiring access. This persistent inadequacy contributes to students continued poor performance in biology ⁵⁵.

The poor learning outcomes in chemistry and other related science subjects at the secondary school level highlight the urgent need to re-examine the teaching and learning conditions under which these subjects are delivered. Critical areas for review include the effectiveness of laboratory activities and the availability of instructional resources that can support student learning. Laboratory work plays a crucial role in promoting understanding of the nature of science, encouraging intellectual and conceptual growth, and fostering positive attitudes toward science. Additionally, it contributes significantly to the development of problem-solving skills, thereby exerting a strong influence on students' overall learning outcomes in chemistry and other science subjects.

Learning outcome refers to the successful accomplishment or performance in a particular subject area. It is often indicated by grades, marks, scores, or descriptive commentaries. More broadly, learning outcomes also describe how students approach their studies, cope with assigned tasks, and accomplish objectives set by their teachers within a specified period or academic year ⁵⁶. The concept of academic self-concept has been used to describe an individual's knowledge and perception of their own academic achievements, alongside their belief in their ability to successfully complete tasks at a designated level. While academic self-concept represents a more past-oriented, aggregated, and relatively stable judgment of one's perceived ability in a particular academic domain, academic self-efficacy is future-oriented and context-specific, reflecting confidence in performing upcoming subject-specific academic tasks.

In contemporary Nigeria, there is a strong emphasis on science and technological development, with particular attention placed on performance in science-related examinations. As a result, students are increasingly encouraged to pursue science subjects. Among these, chemistry stands out as a subject of utmost importance because it permeates nearly every field of human endeavor, including medicine, engineering, pharmacy, agriculture, and more, thereby playing a fundamental role in educational and national development. Despite its relevance, students' achievement in chemistry at the end of secondary education has remained consistently poor. Several factors have been linked to this trend, including the volume of work required, students' task orientation and skill acquisition, personality traits, academic self-concept, feelings of inadequacy, lack of motivation, low self-confidence, anxiety, shortage of qualified teachers, inadequate facilities, poor laboratory equipment and instructional resources, reliance on traditional chalk-and-talk teaching methods, high student-teacher ratios, overloaded curricula, and ineffective content delivery ⁵⁷.

2.2 Theoretical Review

2.2.1 Constructivist Learning Theory

The trend at which the evolution of educational technology and virtual learning has brought about innovations approaches to science education cannot be underestimated, these advancement in teaching strategies has brought constant challenges to traditional means of instruction and raise question about the effectiveness of lecture method of instruction particularly in Chemistry where about ninety percentage of various topics is experimental in nature and as such should be taught in either a physical laboratory or virtual means through animation, videos and

pictures⁵⁸. Volumetric analysis a core aspect of senior secondary school curriculum provides a suitable and context approach to investigate and examine the instructional values of each laboratory learning strategies.

A constructivist learning approach stipulated that learners can actively build their own understanding about knowledge of the world in which they live rather than receiving information which is described as teachers centred⁵⁹. The constructivist learning approach is based on the idea that learning is a gradual process of constructing related meaning through the acquired experiences and reflections which includes eliciting previous knowledge with feedback and reflecting on learning.⁶⁰

The core principles of constructivist learning theory is based on: Active learning which stipulate that learners should not be passive recipients of knowledge or information but should rather engage actively in the construction of their own knowledge, Previous Knowledge in a way that students understanding of new knowledge should be based on previous knowledge, Reflection on experience make learning permanent and social interaction which involve collaborations with peers among others ⁶¹. The key aspect of constructivist teaching includes eliciting prior knowledge, presenting situations that challenge existing knowledge, applying knowledge and feedback, and reflecting on learning.

This theoretical review is based on major and important learning theories and pedagogical frameworks to critically assess how physical and virtual laboratory learning strategies impact positively students' academic achievements in secondary schools. Constructivist learning theory affirm that students or learners actively construct knowledge through hands on practical experience and interact positively with their learning environment. In the usage of physical laboratory learning platform,

students can manipulate learning materials, apparatus, observing chemical processes and reactions, conclude based on their observations, formulate hypotheses and engage actively in inquiry-based learning thereby facilitates deeper understanding of various concepts in experimental chemistry.

In a virtual learning laboratory, constructivist principle is based on operation through simulation that give room for students to explore, play with, manipulate variables and test various hypotheses in an environment devoid of hazard and risk, although the virtual laboratory do not provide the students the opportunity as obtained in physical/real laboratory, where students can manipulate with real laboratory materials and equipment, the interactivity, adequate and immediate feedback in simulation as noticed in virtual laboratory support and facilitate knowledge construction ⁶².

2.2.2 Cognitive Load Theory

The cognitive load theory emphasizes the impediments of working memory and suggest that instructional learning strategy should reduce minimally the numerous and stressful cognitive load⁶³. Virtual laboratory learning strategy through visual and guided procedures can reduce or minimize cognitive overload by ensuring that complex processes are made easy and give room for students to learn and progress at their own pace. Conversely, laboratory learning strategy can make learning more difficult for novice learners who needs to handle complex and flexible apparatus with limited time constrain and this in turn will potentially impedes knowledge acquisition if not properly handled ⁶⁴.

Experimental learning theory is based on the principle that learning occurs through a circle of concrete experience such as reflective, observation, abstract,

conceptualization and active participation in experimental activities ⁶⁵. The physical laboratory learning strategy give room for this model by giving or providing real sensory knowledge and experiences needed in volumetric analysis and more importantly, it enables the learners to have the basic procedures and steps in carrying out volumetric analysis such as normal acid base titration, endpoint determination, accurate volume measurement as well as the basic rules governing the use of Chemistry laboratory ⁶⁶.

Virtual laboratory learning strategy also looks similar to these experiences as applicable to the normal laboratory learning strategy in a way that students can learn digitally with the use of information communication tools such as computer, projector and even smart phones to get the needed experiences and offer repetitive and control exposure which increases learning of difficult and procedural concepts. This may positively benefit visual and reflective learners⁶⁷

2.3. Review of empirical studies

2.3.1 Improvised laboratory and Achievement in Volumetric Analysis

A study examines the effects of improvised laboratory strategy on the academic achievement of undergraduate chemistry students, while also evaluating their potential as viable alternatives or complements to traditional laboratory-based instruction. A pre-test post-test quasi-experimental research design was employed to investigate this effect. The study population comprised forty (40) final-year BSc Chemistry students at Dilla University, who were divided into two groups. The first group (n=20) engaged in improvised laboratory learning, carrying out real laboratory experiments with locally sourced materials. The second group (n=20) served as a control and received only conventional lecture-based instruction.

Quantitative data were gathered using tests administered before and after the interventions to assess academic achievement. A retention test was also conducted two weeks after the post-test to determine knowledge sustainability. Data were analyzed using descriptive and inferential statistical tools, including means, standard deviations, one-way analysis of variance (ANOVA), the Tukey Honestly Significant Difference (HSD) post hoc test, and independent-sample t-tests (two-tailed), with a significance level set at $p \leq 0.05$.

The pre-test results indicated no significant differences in academic achievement among the three groups ($p = .99$), reflecting that all students shared a similar baseline knowledge of volumetric analysis. However, the post-test results revealed significant differences in achievement between the groups. The improvised laboratory group obtained the highest mean score (62.6, SD = 10.7, while the lecture-based group recorded the lowest mean score (43.7, SD = 5.34). ANOVA results confirmed significant differences in the achievement levels across the groups ($F(2,57) = 18.429$, $p < 0.001$). The Tukey post hoc test further showed that the improvised laboratory group significantly outperformed the lecture group (mean difference = 18.88, $p < 0.001$).

In contrast, the improvised laboratory group showed a notable difference in achievement by gender. Male students recorded a higher mean score (9.25, $p = 0.08$) compared to their female counterparts (6.03, $p = 0.05$), suggesting a marginal gender effect in hands-on improvised settings.

The findings of this study suggest that improvised laboratory strategy significantly improve students' academic achievement when compared with conventional lecture methods. These results highlight that improvised laboratory can

serve as effective and viable alternatives when standard laboratories are unavailable, offering engaging and interactive learning experiences for students. Consequently, universities should consider integrating improvised laboratory strategy into their chemistry curricula to enrich the teaching and learning of experimental concepts such as volumetric analysis and to foster improved student achievement. ($F_{2,98} = 0.004$, $p = 0.978$)

2.3.2 Virtual Teaching Strategy and Achievement in Volumetric Analysis

A study examines the effects of virtual laboratory strategy on the academic achievement of undergraduate chemistry students, while also evaluating their potential as viable alternatives or complements to traditional laboratory-based instruction. A pre-test post-test quasi-experimental research design was employed to investigate this effect. The study population comprised forty (40) final-year BSc Chemistry students at Dilla University, who were divided into two groups. The first group ($n=20$) engaged in virtual laboratory learning, carrying out real laboratory experiments through simulations and videos. The second group ($n=20$) served as a control and received only conventional lecture-based instruction. Data were analyzed using descriptive and inferential statistical tools, including means, standard deviations, one-way analysis of variance (ANOVA), the Tukey Honestly Significant Difference (HSD) post hoc test, and independent-sample t-tests (two-tailed), with a significance level set at $p \leq 0.05$.

The pre-test results indicated no significant differences in academic achievement among the two groups ($p = 0.99$), reflecting that all students shared a similar baseline knowledge of volumetric analysis. However, the post-test results revealed significant differences in achievement between the groups. The virtual laboratory group obtained the highest mean score (55.5, $SD = 6.8$), while the lecture-based group recorded the lowest mean score ($M = 43.7$, $SD = 5.34$). ANOVA results

confirmed significant differences in the achievement levels across the groups ($F(2,57) = 18.429$, $p < 0.001$). The Tukey post hoc test further showed that the virtual laboratory group significantly outperformed the lecture group (mean difference = 18.88, $p < 0.001$).

In contrast, the virtual laboratory group showed a notable difference in achievement by gender. Male students recorded a lower mean score ($M = 6.03$, $p = 0.08$) compared to their female counterparts ($M = 7.54$, $p = 0.05$), suggesting a marginal gender effect in hands-on virtual settings.

The findings of this study suggest that virtual laboratory strategy significantly improve students' academic achievement when compared with conventional lecture methods. These results highlight that virtual laboratory can serve as effective and viable alternatives when standard laboratories are unavailable, offering engaging and interactive learning experiences for students. Consequently, universities should consider integrating virtual laboratory strategy into their chemistry curricula to enrich the teaching and learning of experimental concepts such as volumetric analysis and to foster improved student achievement. ($F_{2,98} = 0.004$, $p = 0.978$)

2.3.3 Gender and Achievement in Volumetric Analysis

Gender differences in academic achievement particularly in experimental Chemistry have been an important point in educational research and activities, with findings suggesting that male and female students may respond and perform differently to teaching methods⁶⁸. In science education, studies revealed that Female students generally perform more than their Male counterpart in comprehension and retention of various concepts in Volumetric analysis whereas Male students may excel more than their Female counterpart in technical aspects⁶⁹. This variation in

achievement may be attributed to social, cognitive, and cultural factors highlighting the need for gender-sensitive teaching strategies. As pre-service teachers prepare for careers in education, examining gender as a moderating variable in Volumetric achievement could help identify and address learning gaps, promoting equal access to effective instruction regardless of gender.

In a normal classrooms' settings, these disparities are sometimes influenced by peer dynamics and curriculum design. For example, Male students might receive more attention in science laboratories, while Female students may be encouraged to focus on collaborative or nurturing roles. To create a more equitable education system, it is essential to address the root causes of gender disparities through: Developing inclusive curricula that challenge and encourage both genders to explore diverse fields of study; equipping educators with the skills to recognize and counteract gender biases in their teaching practices; promoting role models of both genders in non-traditional fields to inspire students to break stereotypes; providing mentorship programs, scholarships, and safe spaces to empower underrepresented genders in specific academic disciplines⁷⁰.

Gender can influence academic achievement in a variety of way this includes socialization and expectations which occasionally dictates how male and female students approach learning in an educational environment in such a way that differences in classroom dynamism can be attributed to gender, for example male students might perform better in a competitive environment while the female students may perform better in collaborative settings. others factors may include Teacher's interaction, access to resources, self-confidence and motivation among others.

Gender continues to influence educational access, engagement, and outcomes, shaping the academic trajectories of learners in profound ways. While significant

progress has been made in reducing disparities, achieving true gender equity requires sustained effort from all stakeholders, including policymakers, educators, curriculum planners and communities at large. By addressing systemic biases and fostering inclusive learning environments, society can unlock the full potential of every individual, regardless of gender⁷¹.

The primary aim of the chemistry laboratory and the adequacy of its equipment in secondary schools is to ensure effective laboratory work and the uninterrupted conduct of practical activities. To assess the status of laboratory resources, emphasis must be placed on their adequacy, particularly in relation to student population, since overcrowding can compromise effective use. Adequate laboratory facilities not only make science teaching more concrete and stimulating but also enhance learning outcomes in secondary schools. Research has consistently shown that adequacy of laboratory facilities significantly influences students' academic achievement in chemistry and other science-related subjects⁷². Further investigations confirm that adequate laboratory equipment positively affects achievement in secondary school chemistry teaching⁷³.

The adequacy of science equipment is often a determining factor in the success or failure of the chemistry curriculum. When facilities are lacking, the quality of education is compromised, often reflected in low student achievement, high dropout rates, problem behaviors, poor teacher motivation, and unachieved educational goals. Institutions, being systems of both human and material resources, require the right quantity and quality of these resources to function effectively. When human capital is strategically combined with adequate non-human resources, institutional objectives can be realized⁷⁴. However, recent economic austerity measures and the increasing

demand for education have placed additional strain on resource allocation, making adequacy more difficult to achieve.

Apparatus and equipment are fundamental tools for effective chemistry teaching and learning. Their absence or inadequacy forces teachers to conduct practical activities in abstract terms, often making lessons unengaging and uninspiring. Thus, effective planning for both adequate facilities and the skilled personnel to manage them is crucial for educational success. Educators argue that the adequacy and proper utilization of physical resources remain a pressing concern. Well-utilized resources stimulate students' interest, enhance motivation, and contribute directly to fruitful learning outcomes. Indeed, schools with adequate and properly managed laboratory equipment tend to achieve better academic results compared to those with poorly resourced facilities ⁷⁴.

The management and utilization of equipment are integral to the overall administration of science laboratories. Utilization refers not only to the provision of resources but also to the frequency and effectiveness of their use in teaching and learning activities. Studies reveal that equipment may be available and adequate but still underutilized, thereby limiting their impact on student achievement. Effective utilization of laboratory equipment makes the teaching of chemistry more meaningful and significantly influences students' learning outcomes. In fact, appropriate use of resources stimulates and motivates learners, often serving as a key determinant of academic performance.

Learning effectiveness requires an enabling environment that is both physically and psychologically conducive to learners. Poor learning outcomes are often associated with poorly maintained infrastructures and inadequate facilities. Since

learning is a complex activity influenced by multiple factors including student motivation, physical environment, teaching resources, instructional skills, and curriculum quality no single element can be overlooked ⁷⁵. Nevertheless, the explicit link between school facilities and academic outcomes highlights the importance of both adequacy and utilization. Underutilization or complete neglect of laboratory equipment can limit students' learning outcomes just as much as outright inadequacy ⁷⁶.

The inadequacy of teaching resources remains a serious concern to educators, particularly in the sciences. A common way to determine the influence of science equipment on learning is to examine the level of its utilization in chemistry laboratories. When students adequately utilize laboratory equipment, it fosters desired behavioural change and enhances learner autonomy. Utilization of laboratory facilities is inherently activity-oriented, student-centred, and geared toward self-reliant instruction. Research demonstrates that students who were allowed to manipulate laboratory equipment performed significantly better academically than those who were not provided such opportunities ⁷⁷. This underscores the point that the extent of utilization of laboratory facilities in teaching key concepts in both quantitative and qualitative analysis in chemistry has a direct and significant influence on students' learning outcomes.

Evidence from secondary schools further shows that while many science teachers possess adequate knowledge of how to utilize laboratory facilities, their actual usage is often limited. For instance, studies in biology classrooms revealed that although laboratory facilities were present, most were not adequately utilized, and some were only occasionally available ⁷⁷. This indicates a gradual decline in the era of fully functional and modern laboratories. It is therefore not enough to procure

laboratory facilities; their appropriate and consistent use must be ensured. Teachers bear responsibility for encouraging adequate usage, while government stakeholders must prioritize timely procurement and upgrading of modern laboratory facilities to enhance effective teaching of chemistry and related sciences.

Empirical findings reveal that approximately 74% of science teachers reported utilizing laboratory facilities during practical activities, while 26% admitted to never using them in their instructional practice ⁷⁷. Such data highlight the significant role of laboratory facilities in shaping students' academic achievement. Science teachers are expected to maximize available resources to broaden students' learning opportunities, while school principals must ensure adequate classroom space and the efficient utilization of all resources to achieve educational goals. Practical activities in chemistry not only enhance the acquisition of scientific process skills but also prepare students with competencies that are relevant for contemporary society, fostering employability, wealth creation, and solutions to challenges such as poverty and unemployment.

Nonetheless, recent findings reveal mixed results, with some studies reporting no significant correlation between the utilization of science laboratory facilities and students' academic achievement in chemistry ⁷⁸. This inconsistency may stem from limited or inappropriate use of laboratory resources in schools where such research was conducted. Despite these anomalies, strong evidence supports the view that frequent and purposeful utilization of laboratory equipment is positively associated with improved academic performance. Students who regularly use laboratory resources consistently outperform peers who have limited or no exposure to them, confirming the central role of laboratories in chemistry teaching and learning.

In response to challenges of inadequacy and underutilization, innovative strategies such as the introduction of improvised learning materials and virtual learning platforms have gained prominence. These approaches, particularly in the teaching of volumetric analysis, provide cost-effective alternatives for enhancing student understanding of experimental chemistry. Virtual simulations, videos, animations, pictures, and multimedia presentations have been recognized as powerful tools to promote deeper comprehension of difficult concepts. Numerous studies have examined their role in improving outcomes in volumetric analysis, reporting mixed but generally promising results. Collectively, these strategies represent practical avenues for enriching chemistry education, particularly in resource-constrained environments, and for ensuring that students acquire the necessary conceptual and procedural knowledge to excel in both school-based and external examinations.

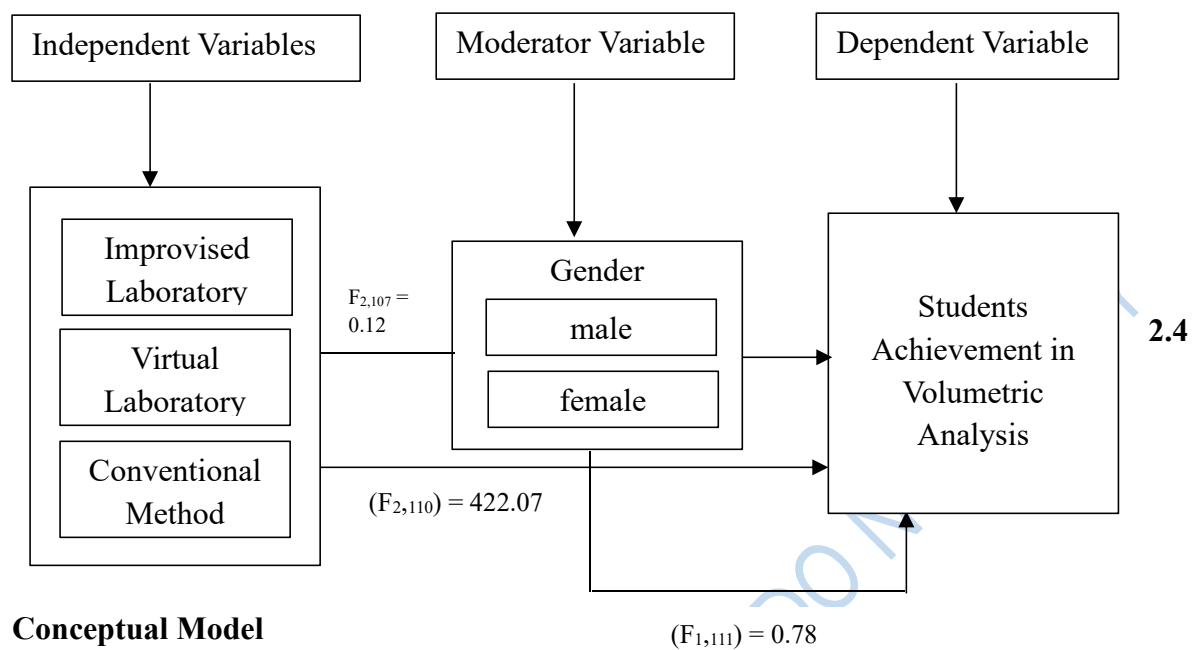


Figure 2.1: Conceptual Model of Improved and Virtual teaching strategies on students' achievement in Volumetric analysis.

Above is the conceptual model of effects of improvised and virtual laboratory teaching strategies on the academic achievement of senior secondary Chemistry students in

Volumetric analysis. It includes the independent variable (teaching strategies and the moderator variable) all pointing towards the dependent variable which is the students' achievement in Volumetric Analysis.

2.5. Summary of Literature Review

Based on the background of the study which exactly is what led the researcher into the study of effect of physical and virtual laboratories on students' academic achievement in experimental chemistry, both major and minor variables were critically review in this chapter.

This chapter indeed critically examine the concepts of physical and virtual laboratories as a tool for students understanding of basic concepts and principles in practical aspect of Chemistry (Volumetric analysis), the nature of physical laboratory and students learning outcome, science equipment and students learning outcome among others.

The provision of physical laboratory in schools have created the need for an evaluation of the adequacy of science equipment, materials and apparatus which seems to be over stretched, hence has a significant effect on the academic performance of schools in Ondo state. World bank indicates that resources availability in schools is inadequate in terms of textbooks distribution, infrastructure availability, teaching aids and teachers to student's ratio. This study therefore aims at putting measure in place to check on the effectiveness of physical laboratories equipment and virtual laboratories on students' academic achievement in chemistry.

The reviewed studies indicate the significant impact of physical laboratory equipment, virtual learning platforms, human resource utilization, school location, and teacher qualities on students' academic achievement in Chemistry, among other factors. While

abundant research exists on the effects of these parameters on education, it is particularly important to understand the role of laboratories—both physical and virtual in shaping learning outcomes. Such understanding is essential for educational stakeholders in Nigeria in order to provide adequate and appropriate resources that will foster improved, effective, and resourceful student learning. The proposition examined in this study is that part of the link between school resource utilization, quality, and educational outcomes is mediated by the availability and effective use of laboratories.

The influence of laboratories, whether physical or virtual, on students' engagement in practical activities has a profound impact on learning outcomes in Chemistry. Active participation of learners enhances motivation, reduces disruptive classroom behavior, and prevents boredom that often results from lessons overloaded with abstract concepts. Participation is strengthened through the effective use of instructional materials and resources that make abstract ideas concrete, thereby facilitating better comprehension of experimental concepts in Chemistry and other related science subjects. In this regard, the teacher plays a central role as a leader whose effectiveness is measured by their ability to initiate ideas, structure and organize learning, manage the classroom, increase students' skills and knowledge, and prepare lessons that are both engaging and challenging. Furthermore, teachers are expected to guide students to success, while also assessing and evaluating their learning accurately.

Several studies have examined the connection between teachers' effectiveness and students' academic performance, with teachers' qualities being central to this relationship. Qualities such as confidence, professional appearance, commitment to duties, positive attitude towards teaching, and respect for students are foundational to

effective instruction. Beyond these, teachers also require relevant academic qualifications, competence in subject matter, the ability to prepare and plan lessons effectively, and the capacity to fabricate and use instructional materials when necessary. Equally important is their ability to inspire and sustain students' interest in learning.

This study also explored teachers' attitudes towards the improvisation of unavailable science equipment, materials, and apparatus required for practical instruction. In many cases, Chemistry teachers fail to adapt or use local materials when readymade instructional resources are unavailable or inaccessible. Improvised instructional materials, however, can be produced either by the teacher or in collaboration with students. The development of such resources is typically initiated by the teacher, and fabrication may involve the teacher themselves or local artisans such as carpenters, blacksmiths, or welders. Teachers may also involve students in the production process, thereby transforming improvisation into a collaborative learning activity. This strategy is particularly valuable in contexts where physical laboratory equipment or virtual laboratory technologies are unavailable, ensuring that the teaching and learning of Chemistry practical activities remain effective and engaging.

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Chapter Three Methodology

The research design, population of the study, sample and sampling techniques, description of research instruments, validity of research instrument, reliability of research instrument, data collection, and data analysis were all considered in this chapter as the methodology for the study coupled with the ethical approval for the study.

3.1 Research Design

The research design for this study is quasi-experimental design of non-randomized and non-equivalent intact group with a 3×2 Factorial matrix using pretest - posttest approach. Two experimental groups and one control group are the focus of the three levels of treatment; the experimental groups were treated with improvised laboratory learning strategy for Group A, Virtual laboratory learning strategy for Group B and the control group, Group C was treated with Conventional teaching

strategy. Further information regarding the research design was described in Table 3.1 and 3.2.

Table 3.1: 3×2 Schematic denotation for the study

Group	1 (Pretest)	Treatment	2 (Posttest)
E ₁	O ₁	X ₁	O ₂
E ₂	O ₃	X ₂	O ₄
E ₃	O ₅	X ₃	O ₆

Source: Researcher's Fieldwork, 2025

Where O₁, O₃, O₅ represents the Pre-test Scores, O₂, O₄, O₆ represents the Post-test Scores and E₁, E₂, E₃ also represent Treatment Groups respectively

X₁ = Treatment 1 (improvised laboratory learning strategy)

X₂ = Treatment 2 (virtual laboratory learning strategy)

X₃ = Control (conventional lecture strategy)

Table 3.2: 3×2 Factorial Matrix Representation

Treatment	Gender
Improvise laboratory strategy	Male / Female
Virtual laboratory strategy	Male /Female
Conventional teaching strategy	Male / Female

Source: Researcher's Fieldwork, 2025

Variables in the study

1. Independent variable includes:

Treatment 1 (Improvise laboratory teaching strategy), Treatment 2 (virtual laboratory teaching strategy), and Control (Conventional teaching strategy)

2. Moderator variable includes: Gender (Male and Female)
3. Dependent variable: Achievement in Volumetric Analysis

3.2 Population of the Study

The study population consists of five thousand two hundred and fifty-five (5,255) Senior Secondary School 2 (SS2) Chemistry Students from Ondo State.

3.3 Sample and Sampling Techniques

The sample consisted of one hundred and fourteen chemistry students from six local government areas of Ondo North senatorial district of Ondo state, Total enumeration method was used for this study. This approach involves collecting information from all members of the target population. It is typically adopted when the study population falls within a manageable size, as it applies to this study which indicates that the data collection instrument was administered to all intact classes of one hundred and fourteen (114) Chemistry students found in the three schools offering chemistry at senior secondary school two (SS2) in Ondo North Senatorial District of Ondo State. Further information regarding the study, see Table 3.4.

Table 3.3: Study Sample

Treatment Groups	Teaching Strategies	Male	Female	Total
Group A	Improvised	18	12	30
Group B	Virtual	20	18	38
Group C	Conventional	24	22	46
Total	3	62	52	114

Source: Researcher's Fieldwork, 2025

A balloting procedure was used to randomly assigned the selected schools to respective groups for the study. The names of the schools were written on individual slips of paper, folded, thoroughly shuffled, and then drawn one after the other. The first school drawn was placed in the Experimental Group A, the second school drawn was designated as Experimental Group B, while the third school drawn was assigned to the Control Group C. As a result of the draw, More High School was placed in group A and received instruction based on improvised laboratory teaching intervention, New Church High School was placed in group B and received instruction using virtual intervention, while Arigidi Comprehensive High School was placed in group C and received instruction through conventional strategy as shown in Table 3.3.

3.4 Research Instruments

Data for this study were gathered using the following instruments:

1. Volumetric Analysis Achievement Test (VAAT).
2. Guide for Instruction in Teaching and Learning volumetric analysis (improvised laboratory learning strategy).
3. Guide for Instruction in Teaching and Learning volumetric analysis (virtual laboratory Learning strategy).
4. Guide for Instruction in Teaching and Learning: Volumetric analysis (conventional Teaching strategy).

3.4.1 Volumetric Analysis Achievement Test (VAAT)

This instrument was used to collect data for this study to assess students' achievement in Volumetric analysis. The instrument consists of 20 items sourced from volumetric Analysis; a topic taught in senior secondary school 2. The questions are multiple-choice in terms of options, which are labelled A – D for the

respondents/students to select only correct answer. The time frame given to students to answer all the questions was 30 minutes.

The Volumetric Analysis Achievement Test (VAAT) consists of two sections. Section A is for the students' Bio data, such as: Name of students, Name of school and gender. Section B is for the 20 multiple-choice questions structured from volumetric analysis in Chemistry. Table 3.4 consists of item specifications for the 20 questions based on the higher order of cognitive levels

Table 3.4: Volumetric Analysis Achievement Test Item Specifications

Skills	Knowledge	Comprehension	Application	Analysis
Percentage	30	20	20	30
Basic concept	2(1,4)	1(6)	1(5)	1(18)
of volumetric analysis				-
Apparatus and equipment	2(2,7)	1(19)	1(10)	1(7)
Safety and laboratory procedure	1(3)	2(14,17)	1(14)	2(13,15)
Acid/ Base	2(11,16)	-	-	1(20)

reaction

Calculation and

Data 1(20)

-

-

interpretation

PH and 3(8,9,12)

2(8,12)

indicator

-

-

Total

20

Source: Research field work 2025

3.4.2 Guide for Instruction in Teaching and Learning volumetric analysis (Improved Laboratory learning strategy)

Using the improvised laboratory learning Strategy in teaching Volumetric analysis allows for an interactive and engaging learning experience. The use of improvised laboratory tools, equipment, and materials facilitates quicker and better understanding and comprehension of processes in Volumetric analysis and increases students' academic achievement. By incorporating these materials and tools, teachers can provide a rich and hands-on learning environment that enhances students' understanding of Volumetric analysis.

The guide for instruction used shall consist of lesson overview (topic, target group, duration, and materials), objective, presentation, assessment and evaluation, closure, and homework. The following steps were taken in the treatment (improved laboratory strategy) presentation:

Instructional guide for experimental Group A: Teaching instructional guide presentation using improvised laboratory strategy to teach Volumetric analysis were as follows:

- A. Introduction
- B. Presentation of the topic
- C. Guided practice Experimental activity
- D. Class discussion and reflection

3.4.3 Guide for Instruction in Teaching and Learning: Volumetric analysis (Virtual Learning strategy).

The virtual strategy in teaching Volumetric analysis allows students to engage actively with practical activities by experimenting in a virtual environment. This hands-on, interactive approach not only makes complex processes more understandable but also enhances student engagement and learning outcomes. By integrating virtual/simulations into the lesson plan, teachers can foster deeper understanding, comprehension and mastery of volumetric analysis, equipping students with both theoretical and practical knowledge in Chemistry.

However, the guide for instruction taken in teaching and learning process in the selected schools for this treatment during fieldwork consist of lesson overview (topic, target group, duration and materials), objective, presentation, assessment and evaluation, closure and homework. The following were steps taken in the treatment (virtual Learning strategy) presentation:

Instructional guide for experimental Group B: Teaching instructional guide presentation using virtual strategy to teach volumetric analysis were as follows:

- A. Introduction
- B. Presentation of new content using videos, pictures

- C. Guided practice
- D. Class discussion and reflection

3.4.4 Guide for Instruction in Teaching and Learning volumetric analysis (Conventional Teaching)

The conventional lecture strategy involves direct interaction and instruction, practice and reinforcement perform by the teacher that is, teacher-led demonstrations, independent exercises and class discussions. This strategy helps students grasp foundational concepts in volumetric analysis. This is more teacher-centred than interactive methods.

Furthermore, the guide for instruction in teaching and learning process in the selected schools for this treatment during fieldwork consists of lesson overview (topic, target group, duration, and materials), objective, presentation, assessment and evaluation, closure, and homework. The following were the steps taken in the treatment (Conventional Teaching) presentation:

Instructional guide for Control Group C: Teaching instructional guide presentation using the conventional teaching strategy to teach volumetric analysis were as follows:

- A. Introduction
- B. Direct instruction
- C. Class discussion and reflection

3.5 Validity of Research Instrument

Face, content and construct validity of the instruments were carried out by the researcher's promoter and lecturers in the Department of Science Education, Lead City University, Ibadan and an expert in Statistics, Test, and Measurement. All corrections were carried out before the field experience by the researcher.

3.6 Reliability of Research Instrument

The reliability of the research instrument, Volumetric Analysis Achievement Test was tested on a set of 20 students outside the researcher's geographical scope but within the population of the study, the scores of the tests were collated and analysed using the Kuder-Richardson 20 (KR-20) formula to test the reliability coefficient of the research instrument (VAAT), the reliability coefficient of the instrument was calculated yielding a reliability value of 0.89

3.7 Data Collection

The process of data collection involves carefully gathering information on participants performances or findings for the particular construct being studied. Research assistants appointed from the selected secondary schools received training. A thorough explanation of the study's goals and the steps required to complete it in eight weeks was covered during the training session. Three research assistants were trained on study-specific methodologies for instruction during the first week of fieldwork. The pre-test was administered to participants in the second week. The implementation of the treatment plan, based on the assigned teaching strategy for each of the selected senior secondary schools, took place over the course of the five weeks (week three to week seven). In week eight, the post-test was administered.

Research assistants from the selected senior secondary schools received training on how to lead students in experimental group A using the improvised laboratory learning strategy, in experimental group B using the virtual learning strategy, and in control group C using the conventional lecture/teaching strategy, while utilising the researcher's prepared instructional guides. Following the training, the researcher observed the research assistants or chemistry teacher as they continued the experiment under the supervision of the researcher for 45 minutes, testing their knowledge of the material. Participants in both the experimental and control groups

were exposed to the same duration of time (periods). Every week for five weeks (week three to week seven), one lecture period (45 minutes) was used in each of the schools where the treatments was administered. Before the commencement of the experiment, the participants were administered the Pre-test, and at the end of the experiment, they were also administered the Post-test. (VAAT)

3.8 Data Analysis

The data collected after subjecting the participants to various forms of treatment were collated and analysed using Analysis of Covariance (ANCOVA) to test the formulated hypotheses for the study at a 0.05 level of significance.

3.9 Ethical Approval

This study adheres strictly to ethical research practices to ensure respect, confidentiality, and voluntary participation of all stakeholders. The researcher obtained a Letter of Introduction from the Head of Department, which was presented to the principal of the selected secondary schools. This letter seeks formal permission to engage with participants and conduct the study, including administering the volumetric analysis achievement test for data collection. Informed consent was obtained from all participants before the commencement of the study. A detailed consent form was provided, clearly outlining the study's purpose, methodology, potential benefits, and any possible challenges. Participants were assured of their rights, including the option to withdraw from the study at any point without any repercussions. The researcher also ensured that all data collected were kept strictly confidential and used solely for academic purposes. Participants' identities and responses were anonymized to protect their privacy. Participation in the study was entirely voluntary, and no participant was coerced into taking part. The research process was designed to minimize any form of harm or discomfort to the participants.

This ethical approach ensures the study adheres to the highest standards of research integrity and respect for participant autonomy.

Chapter Four

Results and Discussion of Findings

4.1: Socio-demographic Characteristics of Study Participants

Table 4.1: Socio-demographic Characteristics of Study Participants

Teaching Strategy	Gender		Total
	Male	Female	
Conventional	24	22	46
Virtual	20	18	38
Improvised	18	12	30

Total	62	52	114
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Source: Researchers Field Work

A total of 114 students were recruited into the study from three different schools, namely More High School, Afo, New Church Grammar School, Owo and Arigidi Comprehensive High School, Arigidi Akoko. Participants were allocated across the three intervention groups, with 46 students assigned to the conventional teaching method, 38 Students for virtual instructional strategy and 30 students assigned to improvised learning method. Table 4.1 presents these details.

4.2: Hypotheses

Table 4.2.1: Main effect of Treatment on Achievement of participants in Volumetric Analysis

Source of Variation	Partial Sum of Square	df	Mean Square	Partial Eta squared	F-value	p-value
Model	3014.28	3	1004.76		345.39	0.001
Strategy	2455.63	2	1227.81	0.884	422.07	0.001
Pretest	1.58	1	1.58	0.004	0.54	0.462
Residual	319.99	110	2.90			

(Error)			
Total	3334.99	113	29.50

Source: Researchers field work 2025, N = 114; Root Mean Square Error = 1.70; R-Squared=0.904; Adjusted R-squared=0.901

As shown in the result (Table 4.3.1), the teaching strategies had a significant ($p\text{-value} < 0.001$) main effect on the academic achievement of the students. The result further revealed that the size of the effect of the teaching strategies was ($F_{2,110}$) = 422.07, with 88.4% variation in the student's achievement being explained by the teaching strategies, as indicated by value of the partial Eta squared. This implies that nearly 88.4% of the student's achievement after the post test was as a result of the study's teaching techniques. Notably, the coefficient of determination (R^2) of the ANCOVA model was 0.904, with its adjusted equal 0.901. This implies that after controlling for potential nuisance variable in the model, the ANCOVA model sufficiently accounts for more than 90% variation in the student's achievement.

Data on the pairwise comparison of student's academic achievement based on assessment of the chemistry students in volumetric analysis Based on the result, the difference (I-J) between academic achievement of students who were assigned to the improvised teaching strategy group (I) and those of the conventional strategy group (J) was 9.52 with an associated 95% confidence interval of (8.75-10.29). This suggests that students in the improvised group had average higher knowledge of 9.52 than their counterparts in the conventional teaching strategy group. Further comparison also revealed a difference of -2.36 between the improvised (I) and virtual (J) strategy group. A negative difference highlights lower achievement in the improvised group, compared to the virtual group. This implies that students in the virtual group had an average 2.36 (95% CI = -3.13 to -1.59) higher post-test knowledge than their colleagues in the improvised group.

Table 4.2.2: Main Effect of Gender on Achievement of Participants.

Source of Variation	Partial Sum of Square	df	Mean Square	Partial Eta squared	F-value	p-value
Model	578.07	2	289.03		11.64	<0.001
Sex	19.42	1	19.42	0.006	0.78	0.378
Pretest	573.02	1	573.02	0.172	23.08	<0.001
Residual (Error)	2756.20	111	24.83			
Total	3334.28	113	29.50			

Source: Researchers field work 2025 N = 114; Root Mean Square Error = 4.98; R-Squared=0.173; Adjusted R-squared=0.158

Results from this study (Table 4.4.2) revealed no statistically significant (p-value=0.378) main effect of gender on the academic achievement of the secondary school students in Volumetric analysis. The result further revealed that the size of the effect of gender was $(F_{1,111}) = 0.78$ with an estimated effect size of 0.006, based on value of the partial Eta squared. This suggests that gender contributed minimally (less than 1 percent, i.e 0.6%) to the overall achievement of the students. Furthermore, the result achieved a low coefficient of determination (R^2) with a value of 0.172, indicative of the fact that 17.3% variation in the outcome variable (student's achievement) was accounted for or explained by the ANCOVA model.

4.2.3: Interaction Effect of Treatment and Gender on Achievement of Participants.

Table 4.4: Interaction Effect of Treatment and Gender on Achievement of Participants.

Source of Variation	Partial Sum of Square	df	Mean Square	Partial Eta squared	F-value	p-value
Model	3019.53	6	503.25		171.08	<0.001
Strategy	2395.85	2	1197.92	0.883	407.24	<0.001
Sex	4.40	1	4.40	0.013	1.50	0.223
Pretest	1.56	1	1.56	0.004	0.53	0.466
Strategy#Sex	0.70	2	0.35		0.12	0.886
Residual (Error)	314.74	107	2.94			
Total	3334.28	113	29.50			

Source: Researchers field work 2025, N = 114; Root Mean Square Error = 1.71; R-Squared=0.905; Adjusted R-squared=0.900

Result of the Analysis of Covariance (ANCOVA) on the interaction effect of gender and the teaching strategies on academic achievement of the student at post-test was $F_{2,107} = 0.12$, with a p-value of 0.886. Considering that the p-value=0.886, this implies non-statistical significance, thus we fail to reject the null hypothesis. The result, therefore suggests that there is no statistical relationship or main effect of the interaction of gender and teaching strategy on academic achievement of the students. The model's coefficient of determination (R^2) was 90.5%, which implies that a high variation in the student's academic achievement is explained by the ANCOVA model.

The results are comprehensively presented in Table 4.4.

Discussion of Findings

The study examined the effects of Two modes of laboratory teaching strategy and gender on the achievement of senior secondary Chemistry students in Volumetric

Analysis in Ondo North Senatorial District, Ondo State, Nigeria. The findings from the Analysis of Covariance (ANCOVA) results for the three null hypotheses are discussed below, with reference to the research objectives, existing literature and implications for Chemistry education.

The null hypothesis, which stated that there would be no significant main effect of treatment on achievement of Chemistry students in Volumetric Analysis, was rejected ($F_{2,110} = 422.07$). The improvised laboratory group adjusted mean significantly outperformed conventional strategy by 9.52. This finding indicates that the use of improvised and virtual laboratory materials, such as locally sourced equipment, videos, animation and pictures for titration experiments, significantly enhanced students' understanding and achievement in Volumetric Analysis. This result aligns with research which found out that hands-on and resource-efficient instructional strategies improve retention and comprehension in science education by making abstract concepts more concrete¹. The large effect size suggests that the two-laboratory strategy accounted for a substantial portion of the variance in post-test scores, highlighting its effectiveness in addressing the challenges of teaching complex topics like titration, as noted in Chapter One. The practical engagement with materials likely enabled students to better grasp concepts such as endpoint determination and concentration calculations, fostering active learning and skill development². The virtual laboratory group achieved the highest adjusted mean when compared to the control group by difference of 11.89 and slightly outperformed the improvised laboratory group with a mean difference of -2.36 as recorded. This finding supports research which reported that simulation-based learning enhances conceptual understanding and procedural skills in science education through interactive, technology-driven environments³. The virtual laboratory strategy, likely involving

digital simulations of titration processes, allowed students to manipulate variables (e.g., titrant volume, indicator changes) and observe outcomes in a controlled, repeatable setting, addressing the limitations of physical laboratories noted in Chapter One. The large effect size (0.884) indicates that the virtual laboratory strategy explained a significant portion of the variance in post-test scores, underscoring its potential as a powerful tool for teaching Volumetric Analysis, particularly in resource-constrained settings like Nigeria where access to fully equipped laboratories may be limited⁴.

The null hypothesis, which stated that there would be no significant main effect of gender on achievement of Chemistry students in Volumetric Analysis, was accepted ($F_{1,111} = 0.78$), this suggests that gender did not influence achievement when the effects of teaching strategies and pre-test scores were controlled. This finding is consistent with minimal gender differences in science achievement when instructional methods are standardized and cognitive factors are accounted for⁵. The negligible effect size indicates that gender accounted for only 0.1% of the variance in post-test scores, suggesting that both male and female students benefited equally from the improvised and virtual laboratory strategies. This address concerns raised in Chapter One about potential gender disparities in Chemistry education, indicating that innovative teaching strategies can create equitable learning environments, reducing biases often observed in traditional laboratory settings⁶.

The null hypothesis, which posited no significant interaction effects of Treatment and gender on achievement in Volumetric Analysis, was accepted $F_{2,107} = 0.12$, The pairwise comparisons and estimated marginal means showed no significant interaction, with differences between genders within each teaching strategy being statistically non-significant ($p > 0.05$). This finding contrasts with studies which

suggested that gender-specific learning strategies may influence outcomes in some contexts⁷. The lack of interaction effect here may be attributed to the standardized implementation of the teaching strategies, ensuring equitable access to resources. The significant effects of both improvised and virtual laboratory strategies highlight their potential to address the challenges of teaching Volumetric Analysis in Nigerian secondary schools, as outlined in Chapter One. Conventional teaching methods, often lecture-based, struggle to convey the procedural and conceptual complexities of titration, leading to poor student achievement. The improvised laboratory strategy, utilizing affordable and locally sourced materials, offers a cost-effective solution for schools with limited resources, making practical Chemistry education accessible. The virtual laboratory strategy, with its superior performance, demonstrates the value of technology in enhancing visualization and interactivity, particularly for abstract concepts like concentration calculations and endpoint detection.⁸. The non-significant gender and interaction effects suggest that these strategies are inclusive, benefiting all students regardless of gender, which is critical for addressing gender disparities in STEM education⁹.

Endnotes

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Chapter five

Conclusion

This chapter sums up the findings of the study, draws conclusions based on the results, and offers practical recommendations for improving Volumetric analysis a concept in Chemistry education in Ondo North Senatorial District, Nigeria. The study investigated how two teaching strategies affect the academic achievement of 114 senior secondary chemistry students in volumetric analysis. It also looked at how gender influences these outcomes. The findings are critically discussed and the recommendations are stated for schools, teachers, and policymakers.

5.1 Summary of Findings

From the Analysis of Covariance results, there was a significant main effect of treatment on academic achievement of Chemistry student in volumetric analysis in Ondo north senatorial district of Ondo state, Nigeria ($F_{2,110} = 422.07, p < 0.05$)

From the Analysis of Covariance results, there was no significant main effects of Gender on academic achievement of Chemistry student in volumetric analysis in Ondo north senatorial district of Ondo state, Nigeria ($F_{1,111} = 0.78, p > 0.05$)

From the Analysis of Covariance results, there was no significant interaction effects of Improvised laboratory strategy, Virtual laboratory teaching strategy and Gender on academic achievement of Chemistry student in volumetric analysis in Ondo north senatorial district of Ondo state, Nigeria. $F_{2,107} = 0.12, p > 0.05$

5.2 Conclusion

The study shows that how teachers teach volumetric analysis makes a significant difference in how well students learn, and gender plays a role too. Improvised laboratory, where students use hands-on tools like burettes or simple plastic containers proves effective in the teaching of Volumetric Analysis, Virtual laboratory, using computer simulations, was most effective. Conventional teaching, with lectures and worksheets, was the least effective showing that just talking and writing on the board does not help students understand complex topics like titration as expected.

These findings are important for schools in Ondo North, where many lack laboratory or computers. Improvised laboratory, using cheap materials like plastic bottles, are a practical way to teach chemistry effectively and fairly for both boys and girls. Virtual laboratory is a good option too, but schools need to provide functional and uninterrupted network facilities and information and communication tools for easy access to online teaching by chemistry students.

This study provides clear evidence that active learning is better than conventional lectures and can help make chemistry education more equal for boys and girls.

5.3: Recommendations

Based on the findings here are the practical steps for schools, teachers and policy makers in Ondo North senatorial district of Ondo State to improve Volumetric analysis teaching in Chemistry towards acceptable learning outcomes.

1. Include the technique of improvised and virtual laboratory as complementary tools in chemistry curriculum as locally available materials such as burette made from plastic syringes and virtual simulations to create a blended learning environment because virtual laboratory

builds the understanding of concepts and improvised laboratory, develop hands on and improve psychomotor skills of students

2. Teachers should ensure understanding of concepts before practical session, teachers can use virtual laboratory to introduce the students to the topic where students will be able to visualise the various steps involved in volumetric analysis, see how end point is been determined and observe colour change before performing the physical experiment in the laboratory
3. Standardise locally sourced materials for safety and accuracy because standardisation maintains reliability and validity of neutralisation such that improvised laboratory can effectively substitute standard laboratory set up in schools with limited or no laboratory resources.
4. Training should be organised for teachers and students by relevant organs on how to source teaching materials locally and also on how to use virtual platform to effectively teach volumetric analysis towards acceptable learning outcomes
5. Virtual laboratory, like PhET simulations, is a good option for schools with computers, schools should offer extra technology training for students before lessons. For example, a short workshop on how to use simulation software could help students feel confident of the use of virtual platform to effectively carry out practical activities.
6. Teachers should add interactive activities, like group discussions or simple demonstration (e.g., mixing an indicator with a base to show a colour change), to make lessons more engaging, especially for girls.
7. Researchers could also test these teaching methods on theoretical aspect and other chemistry topics, like redox reactions, or try mixing hands-on and virtual laboratory to see if that works even better.

5.4 Contribution to Knowledge

1. The two modes of laboratory strategy enhance conceptual understanding in a way that its helps students visualised abstract chemical concepts such as the mole ratio, concentration and

reaction stoichiometry through interactive experiences. Moreover, the strategies increase the students' manipulative skills

2. The two modes of laboratory teaching strategy promote active and experiential learning as students engages in hands on experiment instead of passively listening to teaching by the teachers.
3. The two strategies help the students to develop critical thinking and problem- solving skills by encouraging learners to plan and interpret experimental outcomes,
4. Improvised and virtual laboratory teaching platforms provides alternative pathway to practical chemistry learning in secondary schools lacking fully equipped chemistry laboratory.

5.5 Suggestions for Further Studies

To build on these findings, researchers could:

1. Base the volumetric analysis achievement test on theory questions not only the multiple-choice questions.
2. Investigate how well students retain and transfer knowledge and skills gained through improvised and virtual laboratory teaching to real laboratory settings for future scientific learning, this involves longitudinal studies on knowledge retention and skills transfer.
3. Study the preparedness, attitude and professional development needs of chemistry teachers in implementing improvised and virtual laboratory effectively.

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Appendix I

Volumetric Analysis Achievement Test

Instructions:

Section A: Please provide an appropriate answer to the following questions

Section B: Please Tick only one answer at a time from the given options

Duration: 30 Minutes

Section A

Demographic Characteristics of Participants

Institution's Name: _____

Gender: Male ☐ Female ☐

Section B

1. What is the primary purpose of Titration?
 - A) To dissolve solute
 - B) For temperature measurement
 - C) Concentration determination
 - D) To filter mixture
2. What equipment is used mainly to deliver titrant accurately?
 - A) Pipette
 - B) Burette
 - C) Conical flask
 - D) Measuring Cylinder
3. Which of the following is most important during Titration?
 - A) Using gloves to handle glassware
 - B) Smelling acid and Base
 - C) Wearing safety goggles
 - D) Tasting solution to test Acidity

4. What is the name of the solution of known concentration in a titration?
- A) Analyte
 - B) Indicator
 - C) Titrant
 - D) Product
5. The solution been whose concentration need to be determined is called?
- A) Titrant
 - B) Analyte
 - C) Solute
 - D) Solvent
6. The importance of Indicator in Volumetric Analysis is to
- A) Determine the End-point
 - B) Determine the equivalence position
 - C) Calculate Molarity
 - D) Calculate the Mole Ratio
7. During titration, which apparatus is used to contain the solution been analysed
- A) Burette
 - B) Beaker
 - C) Pipette
 - D) Conical flask
8. Which of the following is a commonly used indicator in acid base titration
- A) Litmus
 - B) Phenolphthalein
 - C) Methyl orange
 - D) All of the above
- 9) A neutral solution has a PH of
- A) Less than 7
 - B) Greater than 7
 - C) Equal to 7
 - D) Not Equal to 7
- 10) The apparatus needed to accurately measure 25cm^3 of Base for Titration is
- A) Conical flask
 - B) Burette
 - C) Pipette
 - D) Measuring Gauge
- 11) The complete reaction between Acid and Base leads to the production of ----
- A) Glycerol

- B) Salt and Water
C) Soap and Propan 1,2,3 Triol
D) None of the above
- 12) What is the colour of Phenolphthalein indicator in a basic medium
A) Pink
B) Colourless
C) Red
D) Yellow
- 13). What type of Titration involves potassium permanganate as the titrant?
A) Acid Base
B) Redox
C) Complexometric
D) Precipitation
- 14) Why is white tile placed under the conical flask during titration?
A) To absorb spilled solution
B) To noticed colour change
C) To keep the flask firm
D) To prevent heating
- 15) An organic solvent either in Acidic or Basic medium used during Volumetric Analysis include the following except
A) Methyl Orange
B) Methyl Red
C) Bromine
D) Phenolphthalein
- 16) The process through which an Acid reacts with a Base to form the corresponding compound is known as
A) Sublimation
B) Saponification
C) Acidification
D) Neutralization
- 17) Which of the following Solvent is use for cleaning apparatus before and after Volumetric Analysis
A) Ammonia Solution

- B) Water
- C) Distilled Water
- D) Glycerol

18). Which of the following describe the role of indicator in titration

- A) To show the end point
- B) To measure the PH
- C) To react with Analyte
- D) To neutralise the Titrant

19) During Acid Base Titration, it is always important to read the Burette from ----

- A) Meniscus
- B) Base Level
- C) The graduated Lines
- D) All of the above

20) The formula to Calculate the Concentration of a Substance in Grams is ----

- A) Conc. in mol dm^{-3} / Molar Mass
- B) $C_a V_a = C_b V_b$
- C) $P_1 V_1 = P_2 V_2$
- D) $PV = nRT$

Answer

1. C
2. B
3. C
4. C
5. B
6. A
7. D
8. C
9. C
10. B
11. B
12. A
13. B
14. B
15. C
16. D
17. C
18. A
19. A
20. A

Appendix II
Teaching and Learning plan
Instructional Guide for Experimental Group A
Teaching Instructional Guide using Physical Laboratory to Teach
Volumetric Analysis

1. Lesson Overview

Topic: Volumetric Analysis (including concepts like Acid- Base Titration, Suitable Indicators, End, point, Measurement and Calculations)

Target Group: Chemistry Students

Duration: 60 minutes

Materials: Retort Stand, Burette, Pipette, Beakers, Conical Flask, known Concentration of Acid, Unknown Concentration of Base, Indicator and distilled water, titration worksheet and calculator, safety goggles and laboratory coat.

2. Objective

To enhance the understanding of key concepts in Volumetric Analysis using Physical Laboratory materials to improve student comprehension, engagement, and academic achievement.

3. Presentation

Content Development	Time (Mins)	Teacher's Activities	Students' Activities
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A. Introduction	10	1. Engage Students: start the teaching by asking the class about their prior knowledge of Acid and Base For example: "What is an Acid, what are the various sources of Acid Can you briefly define a Base . Set the Learning Goal: Inform students that the lesson will be carry out by working directly with the procured teaching aids set up in the Laboratory to help them understand titration which is carried out in the Physical Laboratory. 2. Introduce the Physical Laboratory tools one after the other Briefly, explain how these tools will help in process of carrying out Volumetric activities for better Academic Achievement.	1. Participate in a short discussion about their prior knowledge. 2. Listen attentively to the introduction and expectations of the lesson.
B. Presentation of New Content	20	3.Start with setting out the apparatus and materials needed for the lesson. Introduce the lesson by setting out the precautionary measures when working with toxic Chemicals in a Physical Laboratory, carry out the first practical session and allow Students to see what you are doing. Repeat the second titration process and relate with students as you proceed with the process of titration. Explain in details how you determine the endpoint and how you take the burette readings	3. listen attentively and passionately to what the teacher is teaching. Students watch carefully, understudy the steps been used by the teachers keep watching and listen attentively as the teacher gives instructions on the process of titration, students can ask questions as the activities progresses

		3 Explain to the students how end points are determined, the endpoint is determined when the concentration of both reactants is equal. 4. Balance Chemical equations Ensure that the students are taught how to balance the equation of the reaction between the known and unknown reactants concentration 5. Titration Formula and Calculation. Use $C_a V_a = C_b V_b$ as formula for the calculation and perform simple calculation based on the result of the practical activities. 6. Precautions, State the precautionary measures to be put in place while working in a Physical laboratory such as Avoid error due to Parallax, incomplete mixing of reactants etcetera.	3. The students listen and study the endpoint, that is the point at which there is a noticeable change in colour of reactants. 4. Ensure that students understand the process of balancing a chemical equation for easy calculations 5. Students listen carefully and watch as the calculations are performed asking questions where necessary. 6. Students listen to the precautions and put them into practice
C. Guided Practice	25	1. Provide Guided Activities: Have students complete a set of titration activities to get three consecutive Titre values, ensure that precautions are taken into considerations to avoid injuries	1. Complete Guided Activities: Work individually or in groups to complete the guided practice activities using the Physical laboratory settings.

		2. Calculations, guide the students to perform calculations based on the values obtained from the practical activities 3. Monitor and Assist: Walk around the class and assist students with difficulty in performing the practical activities and supply answers to students' questions	2. Carry out simple Volumetric calculation using the formula $C_a V_a = C_b V_b$ 3. Listen to teachers' corrections when necessary Ask Questions: If needed, ask the teacher for clarification about the concepts or activities.
D. Class Discussion and Reflection	5	1. Facilitate a Discussion: Ask students to reflect on the activities and state important precautions while working in a Physical Laboratory Questions for Discussion: "How did the use of Physical laboratory help you to understand Volumetric concepts better?" "What did you find most interesting or difficult in this lesson?" 2. Summarize the Lesson: Briefly recap the key concepts covered in the lesson 3. Provide Feedback: Offer immediate feedback on student participation and understanding.	1. Reflect and Discuss: Reflect on what they have learned and engage in the class discussion. Share thoughts about how the Physical Laboratory helped them learn. 2. Ask Clarification Questions: If any concepts remain unclear, students should ask questions or request additional examples.

4. Assessment and Evaluation

Teacher's Activity

1. **Formative Assessment:** During the guided practice and class discussion, assess students' understanding by asking targeted questions about Volumetric concepts (e.g., "Can you explain what happens during Titration?").
2. **Summative Assessment:** At the end of the lesson, provide a short quiz or written activity that asks students to apply what they've learned about Volumetric Analysis (e.g., state the color changes when an indicator is added to a solution of Base)

Student's Activity

1. **Participate in the Formative Assessment:** Answer questions from the teacher during the class activities.
2. **Complete the Summative Assessment:** Take the quiz or complete a short reflection on the lesson, applying their understanding of the topics discussed.

5. Closure and Homework

Teacher's Activity

1. **Summarize Key Points:** Recap the key takeaways from the lesson and reinforce how Physical Laboratory Learning Strategy can help students understand Volumetric concepts.
2. **Assign Homework:** Assign students a task related to the lesson discussed in the class.

Student's Activity

1. **Review Notes:** Review the notes taken during the lesson, focusing on key concepts and terms.
2. **Complete Homework:** Follow up on the homework assignment, ensuring that they apply the concepts learned during the lesson.

Appendix III

Teaching and Learning Instructional Guides Instructional Guide for Experimental Group B Teaching Instructional Guide Using Virtual Strategy to Teach Volumetric Analysis

1. Lesson Overview

Topic: Volumetric Analysis (including concepts like Acid- Base Titration, Suitable Indicators, End, point, Measurement, Calculations)

Target Group: Chemistry Students

Duration: 60 minutes

Materials: Virtual laboratory tools, example include PHET interactive Simulations, Labster, Virtual Titration Simulators and Projector or screen to demonstrate simulations

1. **Objective:** To enhance student understanding, procedural skills and Cognitive engagement in Titration without Physical Constraints. by using simulations that allow them to interact with Titration processes, conduct virtual experiments, and apply theoretical knowledge in a practical, hands-on manner.

3. Presentation:

Content Development	Time (Mins)	Teacher's Activities	Students' Activities
---------------------	-------------	----------------------	----------------------

A. Introduction	10	1. <u>Introduce the Topic</u>: Begin the lesson by introducing the topic of volumetric analysis Explain the various concepts in Volumetric analysis such as Acid, Base, Indicators endpoint etcetera. 2. <u>Set Learning Goals</u>: Inform students that they will be using simulation tools to explore how Volumetric analysis is Carried out. 3. <u>Introduce the Simulation Tool</u>: Briefly demonstrate the simulation program that will be used in the lesson, showing how it can simulate Volumetric analytical techniques.	1. Listen attentively to the introduction and objectives of the lesson. 2. Ask questions or express excitement about using the simulation tools for the lesson. 3. Students watch with keen interest.
B. Presentation of New Content Using Simulation	30	1. <u>Demonstrate the Simulation</u>: Show how to perform Volumetric Analysis using the simulation Explain the simulation's interface and how students can learn Volumetric technique using simulator. <u>Teacher Prompt</u>: "In this simulation, you can see how Acid – Base titration is Carried out for you to understand the principle of Volumetric analysis 2. <u>Guide Students Through the First Simulation</u>: Walk Students through the first set of experiments, such as simulating a simple titration involving strong acid and strong base Teacher Prompt: "Let us consider Titrating a strong Acid against a Strong Base, what do you think the endpoint result will be?	1. <u>Set Up and Run Simulations</u>: Each student (or pair of students) runs simulations on their computers/tablets, manipulating variables and study how Volumetric Analysis can be carried out. Student Questions to Answer: what is the importance of indicator in acid base titration 2. <u>Record Observations</u>: Students should record their observations and note the burette reading

		<u>3. Introduce Additional Simulations:</u> Once students are comfortable with the tool, introduce more complex simulations, such as the use of a projector to demonstrate Volumetric analysis. <u>Teacher Prompt:</u> “Let’s now look a practical demonstration of Volumetric Analysis with the use of a projector	3. Experiment with Different Scenarios: Students can experiment with different types of simulators having study the projected laboratory activities, including preparation of dilute Acid form Stock Solution for practical Activities
C. Guided Practice	15	<u>1. Facilitate Group Work:</u> Divide students into small groups, each with a set of simulations to understudy. Each group will use the simulation tool to conduct Volumetric Analysis For example, Group 1 can work on to prepare a dilute solution from stock solution, while Group 2 work on the materials and equipment Group 3 can work on the volumetric Analysis <u>2. Monitor and Assist:</u> Walk around the room, observing student progress and providing support as needed. Offer clarifications and help troubleshoot any issues with the simulation software. <u>Teacher Prompt:</u> “What did you observe when you view the simulator performing the Experiment	1. Collaborate with Peers: Work in groups to conduct Volumetric Analysis using simulation tools Groups will work through their assigned scenarios, analyze the results, and prepare to share their findings with the class. 2. Record Results: Students continue to record the results of their experiments in their worksheets or on an online form. Analyze Data: After completing their experiments, students analyze the results. They should be able to explain their

			respective observations
D. Class Discussion and Reflection	5	1. <u>Facilitate a Class-wide Discussion:</u> Bring the class together and ask groups to share their findings from the simulations. <u>Teacher Prompt:</u> “Can anyone explain the results of your Volumetric Analysis? How did the simulation help you understand the concept Acid Base titration 2. <u>Encourage Critical Thinking:</u> Challenge students to explain what they learned about genetic inheritance and how the simulations helped reinforce the concepts. <u>Teacher Prompt:</u> “What did the simulation reveal about the process of Volumetric Analysis?”	1. Share Findings: Each group shares their results and observations with the class. 2. Engage in Discussion: Students respond to each other’s findings, share insights, and clarify concepts.

4. Assessment and Evaluation

Teacher’s Activity:

1. **Formative Assessment:** Throughout the lesson, assess students’ understanding by observing their participation in the simulations and the accuracy of their recorded results. Ask targeted questions to assess their comprehension of Volumetric concepts.
2. **Summative Assessment:** At the end of the lesson, provide a short quiz or written test on the topics covered in the simulations (e.g., Explain how you will carry out a

Volumetric Analysis in a Physical settings with the experience gathered using simulations

Student's Activity

1. **Participate in Formative Assessment:** Answer questions and demonstrate understanding during group work and class discussions.
2. **Complete Summative Assessment:** Take the quiz or complete an assignment that evaluates their understanding of Volumetric Analysis using simulation tools.

5. Closure and Homework

Teacher's Activity

1. **Review Key Concepts:** Briefly recap the key takeaways from the lesson, reinforcing how simulations helped in understanding Volumetric concepts.
2. **Assign Homework:** Assign students a task that extends the lesson, such as researching calculation using the titer Values or read a chapter from the textbook on Volumetric Analysis.

Student's Activity

1. **Review Notes:** Students should review their notes, ensuring they understand the concepts covered in the lesson.
2. **Complete Homework:** Follow up on the homework assignment, using the knowledge gained from the simulation lesson to further understand Volumetric Analysis.

Appendix IV

Teaching and Learning Instructional Guides Instructional Guide for Control Group C Teaching Instructional Guide Using Traditional Teaching Strategy to Teach Volumetric Analysis

1. Lesson Overview

Topic: Volumetric Analysis (including DNA structure, Mendelian inheritance, dominant and recessive traits, genetic mutations, and Punnett square calculations)

Target Group: Chemistry Students

Duration: 45 minutes

Materials: Chalkboard or whiteboard, Markers/chalk, Projector (optional, for visual aids), Textbooks or handouts and Worksheets for student exercises

2. **Objective:** To teach concepts of Volumetric Analysis such including concepts like Acid- Base Titration, Suitable Indicators, End, point, Measurement, Calculations etcetera.

3. Presentation:

Content Development	Time (Mins)	Teacher's Activities	Students' Activities
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A. Introduction	10	1. Introduction to Volumetric Analysis Begin the lesson by introducing the topic. Explain the Concept of Acid, Base and Salt. Discuss why understanding Volumetric Analysis is crucial in Chemistry 2. Set Learning Objectives: Inform students that they will learn about Volumetric Analysis, Acid Base titration, Indicators, endpoints and simple Volumetric calculations Teacher Prompt: "By the end of this lesson, you should be able to explain the basics processes in Volumetric Analysis, perform simple titration and perform simple calculations using the stated formular	1. Listen to the Introduction: Pay attention to the teacher's explanation of Acid Base and Salt and its importance. 2. Ask Questions: Students can ask any initial questions they may have about the topic or the objectives for the lesson.
B. Direct Instruction	20	1. Lecture on Volumetric Concepts: Provide a lecture on key Volumetric concepts, focusing on: titration and determination of endpoint as well as simple Volumetric Calculations	1. Take Notes: Students listen attentively to the lecture and take notes on the key concepts being discussed 2. Ask Questions: Students may ask questions for clarification
C. Guided Practice	10	1. Practice Problems: Provide students with practice problems on the board or distribute worksheets with Volumetric Analysis, give Class work to elicit immediate responses from the students Example list the suitable Indicators during Acid Base Titration	1. Complete the Practice Problems: Students should individually work on the practice problems provided by the teacher. Record Results:

		2. Work through Examples: Work through a few practice problems with the students, explaining each step of the process. Teacher Prompt: “First, let’s draw the needed materials for Volumetric Analysis technique and set up the apparatus diagrammatically on the board. 3. Monitor Student Progress: Walk around the classroom, offering assistance to students as they complete the problems individually or in small groups. Provide immediate feedback if needed. Teacher Prompt: “What do you get when you carry out the calculation based on the example giving	Students should complete the Class work and submit for teachers’ assessment. 2. Ask for Clarification: Students can ask questions if they are unsure about how to carry out the approach step by step 3. ask for more explanation if the process is not clear enough
D. Independent Practice	10	1. Assign Independent Exercise: Give students a worksheet or ask them to complete a set of problems independently. These should be more complex problems that involve both experimental activities and calculations Teacher Prompt: “Now, I’d like you to try this on your own. Please solve the problem on your worksheet and show the various steps in your calculation. 2. Circulate and Provide Assistance: Walk around to offer support as students work through the exercises. Help students who are struggling but encourage them to complete the task independently.	1. Work Independently: Students should complete the worksheet or exercise on their own, using the concepts learned in the lesson. 2. Review Results: After completing the exercises, students should check their

			answers and revise any mistakes they made.
E. Class Discussion and Reflection	10	1. Facilitate a Discussion: Lead a class-wide discussion to review the students' activities. Ask students to share the results of their independent practice and explain how they arrived at their answers. Teacher Prompt: "Let's discuss your answers to the exercise. What did you get after calculating the concentration of Base 2. Clarify Misunderstandings: Address any common errors that students may have made during the practice.	1. Share Results: Students share their answers and explain how they arrived at their results 2. Engage in Discussion: Students ask questions if they're unsure about any part of the lesson and contribute to the discussion on Volumetric Analysis

4. Assessment and Evaluation

Teacher's Activity

1. Formative Assessment: Throughout the lesson, monitor students' understanding through their participation in class discussions, practice problems, and independent exercises. Offer feedback and assistance as needed.
2. Summative Assessment: At the end of the lesson, assign a short quiz or test on Volumetric Analysis including simple Volumetric Calculation.

Student's Activity

1. **Participate in Formative Assessment:** Engage in discussions and complete practice problems to demonstrate understanding.

2. **Complete Summative Assessment:** Take the quiz or complete the assignment for formal evaluation of understanding.

5. Closure and Homework

Teacher's Activity

1. **Review Key Concepts:** Recap the main concepts covered during the lesson, focusing on the Volumetric Analysis (Acid -Base Titration) and simple Volumetric Calculation.

2. **Assign Homework:** For homework, ask students to list various properties of Acid and Base and perform simple Volumetric calculations

Student's Activity

1. **Review the Lesson:** Students should review their notes and ensure they understand the concepts discussed.

2. **Complete Homework:** Complete the homework assignment on Volumetric Analysis, using textbooks or online resources.

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EDUCATIONAL INSTITUTIONS ATTENDED WITH DATE

- Lead City University, Ibadan, Nigeria 2024-Till Date
- Obafemi Awolowo University, (ACE) Ile-Ife. 2007– 2010
- College of Education Ikere-Ekiti, Ekiti State. 2002 - 2005
- More High School, Afo, Ondo State. 1994 - 2000
- St. David/James Primary School, Afo, Ondo State 1987 - 1994

ACADEMIC QUALIFICATION WITH DATE

M.Sc. (Ed) Chemistry in view 2024- Till Date
Certificate of National Service (NYSC) 2012
Certificate in Computer Studies 2012
B.Sc. in Chemistry Education 2010
National Certificate in Education (NCE) 2005
Senior Secondary School Certificate (SSSCE) 2000
Primary School Leaving Certificate 1994

SKILLS:

- Excellent Oral and Written Skill
- Good computing skill
- Excellent coordination and supervision skill
- Good leadership skill

WORKING EXPERIENCE:

University College Hospital, School of Nursing, Ibadan,

December 2019 - till date

Position- Chemistry Tutor & Member Year One Coordination

Responsibilities

- Applied Chemistry Tutor
- Teaching the contents of the subject curriculum including practical lectures
- Students Coordination
- Documentation of Students scores
- Setting of Questions and marking of scripts
- Supervision/ quarantining of Nursing Students during internal and External examination exercise
- Chairman of the school sports committee
- Secretary quality control committee on e- Learning
- Member Library Committee
- Secretary Staff Forum

More High School, Afo

May 2012 - Nov, 2019

Post Held: Chemistry Teacher

Responsibilities:

- Chemistry Teacher
- Teaching the contents of the subject curriculum
- Taking students attendance and register
- Member of the school sports committee
- Secretary parent's teachers' association
- Evaluating teaching and learning outcomes through test and examinations

College of Education Ikere Ekiti

Office of the Head of Chemistry Department

Feb, 2011- Mar, 2012 (NYSC)

Position: Graduate Assistant

Responsibilities

- Teaching year one Students in Organic Chemistry
- Setting of Questions and marking of scripts
- Invigilation and Supervision of students during examination

- Trainee assistant to the head of department

Publication:

Improvised materials on Chemistry students' achievement in Volumetric analysis in Ondo North, Nigeria. International journal of multidisciplinary studies, 2025

Seminar/Conference

1. Artificial intelligence, research and grants writing training organised by the post graduate college, Lead City University, Ibadan, 15th, Nov, 2024
2. Influence of Virtual Laboratory Learning Strategy on the Academic achievement of schools of nursing students in Volumetric Analysis in Oyo state, Unpublished 6th July, 2025
3. Food and safety hygiene training organised for newly employed staff of University College Hospital, Ibadan by the American Heart Association, December, 2019

HOBBIES: Traveling, Listening to Music, Reading.

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This is to certify that this thesis by Ola Benson ODOFIN with the Matriculation Number LCU/PG/0060889 in the Department of Science Education, Faculty of Education, Lead City University, Ibadan, Oyo State is in full compliance with approved university format and style.

Signature

Date

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