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Effects of Virtual Laboratory on Chemistry Students' Learning Outcomes in Quantitative Analysis in Colleges of Education, Oyo State

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Abstract

Poor performance in practical aspect of Chemistry has been observed over the years in Nigeria Colleges of Education. This was attributed to many problems faced by the teachers in which an alternative of using a virtual laboratory for teaching Chemistry practical for proper understanding is inevitable. This study investigated the "Effects of Virtual Laboratory on Chemistry Students' Learning Outcomes in Quantitative Analysis in Colleges of Education, Oyo State. A quasi-experimental design of 2x2x2 factorial matrix which involved pre-test, and post-test group design was employed. One hundred and thirty six (136) 100 Level NCE students' were purposively selected from two (2) State Colleges of Education in Oyo State. The Chemical Concept Achievement Test (CCAT) (KR20=0.80) was used for data collection. Two hypotheses formulated at 0.05 level of significant and ANCOVA was used for data analysis. Virtual laboratory has a significant main effect on students' academic achievement in Chemistry (F=672.192 Sig=0.000 df= 136 P<0.0). Conventional method has no significant main effect on students' achievement in Chemistry (F=0.10, Sig=0.920, df= 47 P<0.05). It was recommended among others that lecturers in Colleges of Education should be trained regularly through

seminars, workshops, conferences and short-and long-term training on how to use virtual laboratory to improve their competence in teaching and lecture delivery.

Keywords: Virtual Laboratory, Students' Learning Outcomes, Quantitative Analysis.

Word Count: 207

Introduction

Science is recognised as the foundation of contemporary technological advancement throughout the world. The concept of science which have a central place and role can be described as systematic mental representation of the natural world; and this may correspond to observable entities like mammal or mountain, to an unobservable entities like atom or gene (Kampourakis, 2018). Science is a subject that involves working in a laboratory. It is an understanding of natural phenomena that encompasses research and discovery through practical application and experiment conducted with the assistance of teachers (Babateen, 2011).

The core disciplines of science include Chemistry, Physics, and biology. Chemistry being a core discipline in science examines the structure, functions, and interactions of matter. Chemists are curious about the processes that lead to chemical changes. Chemistry plays a significant role in our daily lives (NCERT, 2015). Chemistry is important because everything man does revolve around Chemistry, in fact human body is a composition of chemicals (Lim, 2020). The fact remains that the importance of Chemistry will not be diminished over time, so it will remain a promising career path (Nataˇsa, 2016).

Quantitative analysis involves analyzing substances to ascertain their composition, such as the elements and compounds present in a given sample. Quantitative analysis is the branch of Chemistry that deals with the determination of the amount or percentage of one or more constituents of a sample (The Editor of Encyclopeadia, 2022). Calculations are done to determine the amount of a certain element or compound in a sample. The methods used for quantitative analysis maybe broadly classified as physical and chemical, depending on which properties are utilised. Physical method involves the measurement of some physical quantities like density, refractive index, et cetera.

Chemical method depend on such reactions or precipitation, neutralisation, oxidation which are used in the formation of a new compound. The major types of chemical methods are known as Gravimetric analysis or titrimetric analysis (Volumetric analysis). Chemical methods mainly focus on analysis of chemical reactions and it includes: Titration and Gravimetric analysis.

Titration, also referred to as volumetric (quantitative) analysis, is frequently used to determine how much of an analyte's solute is in its solvent. Analysis of neutralisation reactions between acids and bases is one of its most useful applications. It involves the titration of an acid against base, the end-point of this reaction is determined by colour changes according to the pH of the solution by a substance known as indicator (Wikipedia, 2022).

For a variety of reasons, quantitative analysis is significant in Chemistry: its integration to the pursuit of pure science and very essential to various practical application. It is utilized for medical diagnostic functions, such as determining a patient's blood cholesterol level (and also for determining the biochemical markers biopsied tissues), it plays a vital roles in formulating medicines and processing food products (Onissiphorou, 2022).

Despite the fact that many science and technology courses at Universities, Polytechnics, and Colleges of Education require Chemistry as a prerequisite, and it's importance in the society at large, the rate of students' performance in Chemistry examination has been observed to decline and this may be due to the students, school, and teacher factors at Ordinary Level Certificate Examination, General Certificate of Secondary Education (GCSE) and at Advanced Levels (A-levels). According to the chief examiners report, during the past five years, less than 50% of students have regularly completed Chemistry at the credit level or higher (A1–C6) (WAEC, 2015) (Alexiou, 2005). In educational institutions where both students and teachers contribute to the process outcome, the roles of both parties in the educational process are of utmost importance. Fulfilling the goals of a successful learning process in Chemistry education is frequently a challenging managerial task and complex, three specific learning areas needs to be combined which are the cognitive, affective and psychomotor. The cognitive components is the foundation for

learning which require acquisition of up-to-date factual information; the affective components deals with learners' disposition to chemical concepts with the aim of achieving positive attitude, increased self - awareness and clarification of value. Exposure of students to multiple learning strategies which cannot be provided by conventional method enhances achievement of outstanding success in these areas of learning of Chemistry education.

The world had been transformed into a global village where all activities are achieved through technological tools, devices and resources; and there is a continuous development and occurrence of wide range of technologies which brings about greater potential and possibilities in using technology as a powerful means for instructional deliveries. Learners in this generation are commonly referred to as "NetGen" learners due to the fact that they grew up in environment surrounded by information and communication technology devises and are overwhelmed by continuous technological developments. They prefer to always want to stay connected for interactive and real time experiences rather than non-interactive, passive and non-stimulating environment (Papp, 2010). The educational challenge necessitated by Covid-19 affirmed more the idea of using what appeal to students mind most during teaching learning process, since traditional teaching strategies that are teacher-centered have not provided enough chances for pupils to create their own learning. Students centered instructional methods is a vital means of deriving students' individual capabilities, intelligence and creative thinking (Nataˇsa Rizman Herga, Milena Ivanuˇs Grmek, Dejan Dinevski (2014).

The Chemistry curricula in Nigeria are designed so that ample time is allotted for practical demonstration. The chief examiners' reports from the West African Examinations Council (WAEC) in 2012 and 2013 included, among other things, the unimpressive performance of the candidates (Ramos, S., Pimentel, E. P., Marietta, Maria das G. B., Botelho, W. T. (2018). The papers stated that students were unable to draw logical conclusions from experimental findings. The lack of knowledge with the use of basic laboratory tools has been linked to students' poor performance, particularly in the practical aspects of Chemistry. Effective utilisation of laboratory resources can help

students better understand abstract Chemistry concepts since students require practical experiences to understand these concepts (Alexiou, 2005). The Colleges of Education students' performance in Chemistry were not encouraging due to their poor foundational backgrounds in Chemistry in secondary schools as a result of lack of laboratory, or equipment and poor laboratory conditions.

Although, the use of laboratories in classroom instruction is very vital and essential, there are some restrictions and issues, particularly in poor nations. The following are some of the main issues encountered: the cost of conducting experiments and setting up the necessary equipment; the length of time required for planning and implementation; the difficulty of assessing students' performance during activities in crowded classrooms; and the teacher's limited ability to perform even the most basic of laboratory activities due to a lack of facilities or equipment (Nataˇsa Rizman Herga, Dejan Dinevski, 2012).

In the real world situations taking cognizance of the limits and problems, sometimes due to the limitation of equipment, limited time allocated for the topic or insufficient laboratory conditions force teachers to perform laboratory activities in crowded groups, or sometimes demonstrational activity can be performed. This application is contrary to the basic laboratory method ethics which accepts that knowledge can be gained through personal experience and observation (Nataˇsa Rizman Herga, Dejan Dinevski, 2012).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 computer in supporting the laboratory methods can be a logical one (Tuysuz, 2010).

To solve the various problems faced under conventional method, one of the valid intervention used to solve the problem is the use of virtual laboratory. People are constantly looking for ways to make knowledge transfer easy, quicker, and more effective. Virtual laboratory seems to be the natural next step for the evolution of education (Georgiou, Dimitropoulos, & Manitsaris (2007). Many researchers and educational practitioners opined that virtual laboratory technology has provided new insights to support education.

A virtual laboratory is the most fascinating breakthrough of the digital age that may be applied to the field of education. The interesting laboratory processing and simulation facilities provided by the virtual laboratory make it easier to use tools and produce findings that are more accurate (Tatli & Ayas, 2012) The virtual laboratory is a teaching tool that effectively offers direct, hands-on experiment visualization, an interactive virtual environment, and more opportunities to redo failed experiments to further the learning process independently (Ramadhan, & Irwanto (2017); Tatli & Ayas, 2012).

The development of virtual laboratories facilitate numerous distinct benefits which include equipment reduction needs, availabilities at all times when and where needed in attaining the expected learning outcomes (Gambari, Kawu, & Falode 2018).

The virtual laboratories, a learning medium which enhances academic pursuits contributes positively in achieving learning goals by solving some problems faced in conventional laboratories (Georgiou, Dimitropoulos, & Manitsaris, 2007). Utilising virtual laboratories effectively improves learning through practice in a more affordable and safe setting, and once available at an affordable price (Tatli & Ayas, 2012). The use of virtual laboratories greatly facilitates and improve learning process of science through simulations but cannot replace traditional laboratories (Kathleen, & Pedersen 2021).

Therefore, the use of virtual laboratory or simulation programs, overcomes some of the problems faced in traditional laboratory applications and make positive contributions in reaching the objectives of an educational system. Use of simulation programs can overcome that mistakes which occur as a result of such laboratory conditions or misuse of the laboratory (Lim, 2020). The risk that may be avoided in which a hazardous experiment can be prepared in computer simulations for students to view the experiments design, run the experiment in computer, and observe the result is one of the greatest benefits of virtual laboratories over the real laboratories. Difficult experiments can be done virtually having advantages of time saving, reduced cost and increased motivation compared to real laboratory which faced lack of equipment, costly materials and

dangerous situations (Nataˇsa, & Dinevski (2012); Wong, Chen, & Chang (2020).

The urgent need for Nigeria to gradually and steadily move away from the traditional time-tested methods and techniques of instruction and embraced the idea and implementation of ICT-based teaching strategies. Because of this, research on the impact of virtual laboratories on students' performance in practical Chemistry in a personalized and collaborative context is few in Oyo State, Nigeria. This study seek to find out the effects of virtual laboratory on students learning outcomes in quantitative analysis in Chemistry in Colleges of Education, Oyo State.

Statement of the Problem

Poor performances in the practical aspect of Chemistry especially in quantitative analysis has been observed over many years most especially since the COVID 19 era in which academic activities were crippled for a long period of time. The performance of students' in practical Chemistry which facilitates meaningful learning is very poor in Nigeria (Hamed & Aljanazrah, 2020). The poor performance is attributed to limitation of the teacher to perform simple laboratory activities due to packed classrooms, lack of laboratories or equipment, or inadequate laboratory settings, the cost of conducting experiments and setting up the necessary equipment; the length of time required for planning and implementation; the difficulty of assessing students' performance during practical activities in crowded classrooms. This could be due to the fact that both students' and teachers are not familiar to the virtual laboratory and we are in the era of technology, there is need for the students' to be exposed to virtual laboratory in order to improve the students' learning outcomes. Existing work had been done on the conventional method. However, there is paucity of work in the use of virtual laboratory in teaching quantitative analysis, an aspect of Chemistry practical in Colleges of Education. This study therefore focus on the Colleges of Education whose Chemistry students are not conversant with the use of virtual laboratory and would need information and orientation on virtual laboratory. It is on this note that this study was carried out to investigate the effects of

virtual laboratory on Chemistry students' learning outcomes in Quantitative analysis in Colleges of Education, Oyo State.

Aim and Objectives of the Study

The aim of this study is to examine the effects of virtual laboratory and conventional learning on Chemistry students learning outcomes (Achievement) in quantitative analysis in Colleges of Education, Oyo State.

Specifically, the objectives of this study are to:

(i) determine the main effect of using virtual laboratory on students' learning outcomes (Achievement) in quantitative analysis in Chemistry in Colleges of Education, Oyo State.

(ii) examine the main effect of using conventional method on students' learning outcomes (Achievement) in quantitative analysis in Chemistry in Colleges of Education, Oyo State.

Hypotheses

The following null hypothesis will be tested at 0.05 level of significant.

$H_0$1: There will be no significant main effect of virtual laboratory on Chemistry students' learning outcomes: (Achievement) in quantitative analysis in Colleges of Education, Oyo State.

$H_0$2: There will be no significant main effect of conventional method on Chemistry students' learning outcomes (Achievement) in quantitative analysis in College of Education, Oyo State.

Methodology

The research design of the study was a quasi-experimental design of 2x2x2 factorial matrix. It focuses on treatment which was of two levels (virtual group and control group). Virtual laboratory and conventional method were independent variables, in which virtual laboratory was used for the experimental group while the conventional teaching method was used for the control group. The dependent variable were learner's achievement in pre-test and post-test approach.

The population for the study comprised all 100 level chemistry students from the Emmanuel Alayande College of Education, Erelu,

Oyo and the Oyo State College of Education, Lanlate in Oyo State. The population of chemistry students at the Emmanuel Alayande College of Education was three hundred and ninety one, while the total population of chemistry students in Oyo State College of Education, Lanlate was one hundred and sixty-nine. The total population for the study was five hundred and sixty students of the schools in consideration.

The study used the purposive sampling technique to select one hundred and thirty six of two intact classes of NCE 1 chemistry students of the Alayande College of Education, Erelu, Oyo and NCE 1 chemistry students' of Oyo State College of Education, Lanlate, Oyo State. The study adopted the use of NCE 1 Chemistry students because the quantitative analysis in Chemistry was been taught in 100 level.

Research Instruments

The research instruments used for this study were Chemistry Virtual Laboratory (CVL), Chemical Concept Achievement Test (CCAT).

(a) Chemistry Virtual Laboratory (CVL)

Chemistry Virtual Laboratory was an instructional software developed by the researcher for teaching and learning Chemistry at Colleges of Education; it is used as a treatment to support learning using computer as a medium. The CVL was developed with three (3) components which include: (a) Chemistry lecture note, (b) video of Chemistry practical, (c) Virtual Chemistry Laboratory. The Chemistry lesson plan format enables students to read the experimental procedure and guide the teaching of quantitative analysis as the core of the study.

Video component were recorded using digital camera and editing suite to enable students watch the video of Chemistry practical and the Chemistry Virtual Laboratory enable the students to perform the experiment. CVL consists of three topics which include: (a) Introduction to Quantitative Analysis (b) Preparation of Standard Solution, and (c) Determination of Unknown Concentration. Each of these topics were taught for 60-minutes per week. The production of the Chemistry Virtual Laboratory were effected through a team of professionals and specialists that include: (a) computer programmers,

educational technology experts; Chemistry lecturers and laboratory assistants.

(b) Chemistry Concepts Achievement Test (CCAT)

The Chemical Concepts Achievement Test (CCAT) was used for data collection in which the students' were given the Chemical Concepts Achievement Test (CCAT) as pre-test before the treatment. It was based on the contents of CVL. CCAT consisted of forty objectives questions. Chemical Concepts Achievement Test (CCAT) were answered by the students. It has two sections. Section A consists of Demographic Data of the students. Section B comprises forty multiple choice questions which were self-structured to test the students' achievement in Chemistry. The instrument were scored manually; one mark was awarded for each correct answer, while zero was awarded for wrong answer. The total mark obtained was forty marks.

Validity and Reliability of Research Instrument

Face and content validity evidence were used to validate the questionnaires. The data collected from the pilot study was used to determine the reliability coefficient using Kuder Richardson of KR20 = 0.8, was obtained to ensure its dependability.

Table 1: Frequency Table Showing the Schools of the Respondents

Name of schools	Frequency	Percentage	Cumulative percentage
Emmanuel Alayande College of Education	88	64.71	64.71
Oyo State College of Education Lanlate	48	35.29	100.0
Total	**136**	**100**	

Source: Fieldwork, 2022

Table 1 shows that the 88 (64.71%) of the respondents were from Emmanuel Alayande College of Education, while the remaining 48 (35.29%) of the respondents were from Oyo State College of

Education, Lanlate. Most of the respondents were tilted towards the Emmanuel Alayande College of Education, Erelu, Oyo.

Presentation of Tests of Hypotheses

$H_0 1$: There will be no significant main effect of virtual laboratory on Chemistry students' learning outcomes (Achievement) in quantitative analysis in the colleges of education in Oyo State.

Table 2: Analysis of Covariance (ANCOVA) showing the main effect of virtual laboratory on Chemistry students' learning outcomes (Achievement) in quantitative analysis in Colleges of Education, Oyo State.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1540.663[a]	2	770.332	336.825	0.000	0.777
Intercept	1344.275	1	1344.275	587.780	0.000	0.753
Pre-test	1.371	1	1.371	0.599	0.440	0.003
Virtual Lab	1537.327	1	1537.327	672.192	0.000	0.777
Error	441.398	135	2.287			
Total	13370.000	136				
Corrected Total	1982.061	136				

a. R Squared = .777 (Adjusted R Squared = .775)

Source: Fieldwork, 2022

Table 2 indicates that there is a significant main effect of virtual laboratory on students' academic achievement in Chemistry F-ratio is 672.192, with associated probability (P = 0.000). Meanwhile the Probability value of 0.000 is less than 0.05 level of significant. The partial Eta squared (0.777) showed that virtual laboratory has a great effect on the academic achievement of quantitative analysis in Chemistry (0.777) accounting for 77.7% of the effect. Hence, it could be concluded that virtual laboratory had significant effect on students' learning outcomes (Achievement) in quantitative analysis in Chemistry in Colleges of Education. The null hypothesis that there will be no

significant main effect of virtual laboratory on Chemistry students' learning outcomes (Achievement) in quantitative analysis in Colleges of Education in Oyo State is therefore rejected.

$H_0$2: There will be no significant main effect of conventional method on students' learning outcomes (Achievement) in quantitative analysis in Chemistry in College of Education, Oyo State.

Table 3: Analysis of Covariance (ANCOVA) showing the main effect of conventional method on Chemistry students' learning outcomes (Achievement) in quantitative analysis in Colleges of Education, Oyo State.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	0.174[a]	1	0.174	0.010	0.920	0.000
Intercept	754.013	1	754.013	44.479	0.000	0.492
Pretest	0.174	1	0.174	0.010	0.920	0.000
Conventional	0.398	1	0.398	441.3	0.920.	0.000
Error	779.805	46	16.952			
Total	12845.000	48				
Corrected Total	**779.979**	**47**				

a. R Squared = .000 (Adjusted R Squared = -.022)

Source: Fieldwork, 2022

Table 3 shows that there is no significant main effect of conventional method on students' academic achievement in Chemistry F-ratio is 0.10, with associated probability (P=0.920). Meanwhile the Probability value of 0.920 is greater than 0.05 level of significance. The partial Eta squared (0.00) showed that conventional method had no positive effect on the academic achievement of quantitative analysis in Chemistry (0.00) accounting for 0.00% of the effect. Hence, it could be concluded that conventional method had no significant effect on students' learning outcomes (Achievement) in quantitative analysis in Chemistry in Colleges of Education. The null hypothesis that there will be no significant main effect of conventional method on students'

learning outcomes (Achievement) in quantitative analysis in Chemistry in Colleges of Education in Oyo State is therefore accepted.

Discussion of Findings

The study was carried out to examine the effects of virtual laboratory on the Chemistry students' learning outcomes (Achievement) in quantitative analysis in Colleges of Education. The demographic information of the students revealed that eighty-eight (88) (64.71%) students from Emmanuel Alayande College of Education, Erelu, Oyo participated, while forty-eight (48) (35.29%) students from Oyo State College of Education, Lanlate participated in the study. The number of students were not the same because of the variation in population of the students in the different location. The implication of this was that most schools in rural areas was characterised by low population whereas schools in urban areas were crowded.

The findings of this study revealed that there is a strong positive significant effect of virtual laboratory on students' learning outcomes (Achievement) in Quantitative analysis in Chemistry among Colleges of Education in Oyo State. Virtual laboratory was seen to have a great and positive effect on students offering Chemistry based on the achievement test outcomes. Chemistry students taught with virtual laboratory record high academic achievement than those taught with the use of conventional methods. In a study, more than 80% of students who used virtual laboratories scored higher in examinations compared to a control group (Kumar et al, 2018; Asiksoy & Islek, 2017). This corresponds with the view that virtual laboratories offer numerous advantages for reaching the anticipated learning outcomes; and the usage of virtual laboratories addresses some of the issues with traditional laboratories and helps students achieve their learning objectives (Georgiou et al., 2007). Additionally, it was discovered that using virtual laboratories in Chemistry classes as an alternative method of instruction might significantly enhance student learning outcomes (Tatli & Ayas, 2013).

The results from the findings revealed that students in the treatment group performed better than those taught with the use of conventional methods; the introduction of virtual laboratory package made the experimental group performed better than the control

group (Famuwagun & Mohammed 2020). The experimental group scored much higher on the physics achievement test than the control group, according to a study that evaluated the effects of a virtual laboratory with a traditional laboratory on academic achievement, student teachers' cognitive achievement and practical skills (Hamed & Aljanazrah, (2020); Faour & Ayoubi, (2018); Asare et al; 2022). The result of a study revealed a positive effect on the application of virtual laboratory of problem-based learning to improve scientific literacy and problem-solving skills among junior high school students (Supahar & Widodo 2020)

This result supported the idea that using audiovisual teaching resources aids in students achieving excellent academic scores[6]. The exciting laboratory processing and simulation facilities, tool simplicity, conduct of experiments at their own learning pace, and more precise findings, were all provided by the virtual laboratory (Tatli & Ayas (2012); Asiksoy & Islek, 2017). Students can individually expand their understanding by repeating the incorrect experiment using the virtual laboratory activity (Tatli & Ayas (2012); Ramadhan & Irwanto 2017).

The results of the finding which stated that there is no significant main interaction effect of conventional method on students' achievement in Chemistry is accepted, F-ratio is 0.10, with associated probability (P = 0.920), the Probability value of 0.920 is greater than 0.05 level of significance. The partial Eta squared (0.00) showed that conventional method had no positive effect on the academic achievement. Conventional method was discovered not to be a better option for learners with varying character and needs in learning Chemistry. Students' learning outcomes and achievement in conventional Chemistry classroom were influenced by many factors; and among the numerous were the strategies or methods of teaching, students' conceptual understanding, problem-solving skills, students' gender, school type and many others. Studies have revealed that the quality of scientific instruction in secondary schools in Nigeria falls short of expectations; the majority of teaching strategies have been deemed ineffective and uninspiring (Ibe, 2004). It is also asserted that there was no best method of teaching, but that effective scientific teaching should be laboratory-centered and activity-oriented (Nnaobi, 2007).

Conclusion

It was concluded that students' attitude towards quantitative analysis was moderate. Also, this study had established that though conventional method was not bad, virtual learning were both more effective instructional mode that can be used to improve students' learning. In this era of digital devices, a better way to solve the various problems faced under conventional method is the introduction, appropriate and adequate use of virtual laboratory to all the level of education offering Chemistry including Colleges of Education. This will make knowledge transfer easy, more retaining, quicker, and teaching more effective.

Recommendations

Based on the foregoing, the following recommendations are suggested to be considered:

1. Students should be introduced to virtual laboratory from secondary schools to avoid being shy away from the advanced equipment once in higher institution. Schools' laboratories should be built or renovated, equipped with adequate and appropriate technological devices that are learners friendly, which will help keep the interest of the students within the laboratory to learn more.
2. Lecturers and students must break away from the old pedagogical beliefs underlying teaching, teaching and learning should be blended and made teacher-learner centered, if not purely learner-centered. Lecturers should be trained regularly through seminars, workshops, conferences and short and long term training on how to use virtual laboratory to improve their competence in teaching and lecture delivery. All lecturers in Colleges of Education should have access to the internet at homes and in the offices. The College environment must be made ICT- compliant as it is in the University.
3. Virtual laboratory should be encouraged. There should be a thorough monitoring by the concerned bodies on the implementation of virtual devices in both rural and urban schools.

This is to prevent some sets of students being deprived of effective method of teaching especially in learning Chemistry.

References

Alexiou, A. (2005). Christos Bouras, Eleftheria Giannaka: *Virtual Laboratories in Education. A Cheap Way for School to Obtain for All Courses by Using the Computer Laboratory*. https://www.researchgate net /publication /239531964.

Asare, A. H. Y., Annan J. N. & Ngma-Wara E. I. (2022). *The Effects of Virtual Laboratory on Students Teacher's Achievement in Integrated Science in Bagabaga College of Education, Tamale, Ghana.* European Journal of Research & Reflection in Educational Sciences. 10(2), 26-39

Asiksoy, G. & Islek D. (2017). *The Impact of Virtual Laboratory on Students' Attitudes in a General Physics Laboratory*. International Journal of Education, 13(4), 21-28 http://www.i-joe.org

Babateen H. M. (2011). *The Role of Virtual Laboratories in Science Education,* 5th International Conference on Distance Learning and Education IPCSIT, IACSIT Press, Singapore 12, 100-104.

Famuwagun, S. T. & Mohammed N. N. (2020). *Effects of Virtual Instructional Package on Senior Secondary School Students' Performance in Chemistry in Ondo State, Nigeria*. Kashere Journal of Education, 1(2), 55-63

Faour, M. A. & Ayoubi, Z. (2018). *The Effect of using Virtual Laboratory on Grade 10 Students' Conceptual Understanding and their Attitude Towards Physics,* Journal of Education in Science, Environment & Health, 4 (1), 54-68.

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

Gunawon, G., Nisrina, N., Suranti, N. M. Y., Herayanti, L. & R. Rahmatiah (2018). *Virtual Laboratory to Improve Students' Conceptual Understanding in Physics Learning*. Journal of Physics: Conference Series 1108, 2018 doi:10.1088/1742-6596/1108/012049

Georgiou, J., Dimitropoulos, K. & Manitsaris A. (2007) *A Virtual Reality Laboratory for Distance Education in Chemistry".* International Journal of Social and Human Sciences, 1, 306–313.

Hamed, G. & Aljanazrah, A. (2020). *The Effectiveness of Using Virtual Experiments on Students' Learning in the General Physics Lab.* Journal of Information Technology Education: Research, 19, 976-995. https://doi.org/10.28945/4668 (CC BY-NC 4.0).

Ibe E. (2004). *Effects of Guided-Inquiry and Demonstration on Science Process Skills Acquisition among Biology Secondary School Students,* Unpublished M.Ed. Thesis, University of Nigeria, Nsukka.

Ibe, E. & Abamuche, J. (2019). *Effects of Audiovisual Technological Aids on Students' Achievement and Interest in Secondary School Biology in Nigeria, Department of Science Education, Faculty of Education, University of Nigeria, Nsukka, Nigeria,"* Journal of Education 5.

Kampourakis K. (2018). *On the Meaning of Concepts in Science Education,* Science & Education 27, 591–592. Available online https://doi.org/10.1007/s11191-018-0004-x

Kathleen, Hess M. & Pedersen, Lee A. (2021). *Incorporating Chemical Information Literacy into Large Organic Chemistry Classes through the Laboratory,* ACS Symposium Series, 1232, 121-141.

Kumar, D., Radhamani, R., Nizar, N., Achuthan, K., Nair, B, & Diwakar, S. (2018). *Virtual and Remote Laboratories Augment Self Learning and Interactions; Development, Deployment and Assessments with Direct and Online Feedback,* Peerj Preprints, Available online https://doi.org/10.7287/peerj.preprints.26715v1.

Lim, A. (2020). What is Chemistry? https://www.livescience.com/45986-what is chemistry.html

Nataˇsa Rizman Herga, Dejan Dinevski (2012). *Virtual Laboratory in Chemistry- Experimental Study of Understanding, Reproduction, and Application of Acquired Knowledge of Subject's Chemical Content".* Organizacija, 45, (3), 108–116.

Nataˇsa Rizman Herga, Milena Ivanuˇs Grmek, Dejan Dinevski (2014). *Virtual Laboratory as an Element of Visualization when Teaching Chemical Contents in Science Class,* The Turkish Online Journal of Educational Technology, 13, (4), 157–165.

Nataˇsa Rizman Herga (2016). *Virtual Laboratory in the Role of Dynamic Visualization for Better Understanding of Chemistry in Primary School,* Eurasia Journal of Mathematics, Science & Technology Education, 12(3), 593-608.

NCERT. Some *Basic Concepts of Chemistry.* (2015) https://ncert.nic.in./ncerts/1/kech101.pdf 2015

Nnaobi A.F. (2007) *Teaching Qualitative Inorganic Component Analysis in Colleges using Multiple Methods*, Journal of Science Teacher Association of Nigeria, (3), 87- 91.

Onissiphorou Kate: *How is Qualitative Analysis used in Chemistry?* reagent.co.uk. 2nd March 2022.

Papp R. (2010). *Virtual Words and Social Networking: Reaching the Millennial,* Journal of Technology Research, 2, 1-15.

Ramadhan, M. F. & Irwanto (2017). *Using Virtual Labs to Enhance Students' Thinking Abilities, Skills and Scientific Attitudes,* International Conference on Education, Research and Innovation (ICERI), 494-499.

Ramos, S., Pimentel, E. P., Marietta, Maria das G. B., Botelho, W. T. (2018). *Hands-on and Virtual Laboratories to Undergraduate Chemistry Education":* Toward a Pedagogical Integration, (FIE), IEEE, 1-8.

Santos, M. L. & Prudente M. (2022). *Effectiveness of Virtual Laboratories in Science Education: A Meta-Analysis.* International Journal of Information and Education, 12(2), 150-156 doi:10. 18178/ijiet2022.

Supahar, & E. Widodo (2020). *The Effects of Virtual Laboratory Application of Problem-Based Learning Model to Improve Science Literacy and Problem-Solving Skills*. Advances in Social Science, Education and Humanities Research, 528, 1-8.

The Editors of Encyclopedia Britannica, 4th March, 2022.

Tatli, Z. & Ayas, A. (2012). *Virtual Chemistry Laboratory: Effect of a Constructivist Learning Environment,* Turkish Online Journal of Distance Education, (TOJDE), 13, (1), 183–199.

Tatli, Z. & Ayas, A. (2013). *Effect of a Virtual Chemistry Laboratory on Students' Achievement,* Educational Technology & Society, 16(1), 159-170. Available online https://www.jstor.org/stable/jeductechsoci. 16.1.159.

The Editors of Encyclopedia Britannica, 4th March, 2022 T¨uys¨uz, Cengiz (2010). *The Effect of the Virtual Laboratory on Students' Achievement and Attitude in Chemistry".* International Online Journal of Educational Sciences, 2 (1), 37–53

Wikipedia *"Qualitative Analysis (chemistry)* available online 11th March, 2022

Wong, W. K., Chen, K. P. & Chang, H. M. (2020). *A Comparison of a Virtual Lab and a Microcomputer Based Lab for Scientific Modeling by College Students,* Journal of Baltic Science Education, 19 (1), 157-173.