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Effect of Virtual Laboratory Instruction on Secondary School Biology Students' Achievement in Kwali Area Council, Abuja, Nigeria

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Abstract. *The study investigated the "Effect of Virtual Laboratory Instruction on Senior Secondary School Students' Achievement in Biology in Kwali Area Council of F.C.T". The study adopted the quasi-experimental pre-test/post-test control group design. The sample in the study consisted of 78 senior secondary school II Biology students selected from two Local Government Area using purposive sampling techniques. The students in the experimental group were exposed to virtual laboratory strategy while the control group was taught Biology with the conventional method. The instrument used in the study was Biology Achievement Test (BAT) to collect data for the study. The reliability coefficients of the study was obtained using Kuder-Richardson for BAT with the value of 0.86. Data were analyzed using mean and standard deviation to answer the two research questions while t-test was used to test the two null hypotheses generated for the study at 0.05 level of significance. Findings revealed that, there was significant difference in the mean achievement scores of secondary school students taught Biology using virtual laboratory strategy as against their counterparts taught biology using the conventional method. However, there was no significant differences in the mean achievement scores of male and female students taught Biology using virtual laboratory. Therefore, recommendations were made among others that teachers should be adequately trained in the use of educational technologies. Workshops, seminars, and continuous professional development programs should be organized to equip biology teachers with the skills necessary to incorporate virtual labs into their instructional practices effectively.*

Key words: *Biology, Achievement, Virtual Laboratory Instruction.*

Introduction

Education is the foundation of any nation's development. It is through education that societies transmit knowledge, skills, attitudes, and cultural values from one generation to another, thereby fostering both individual and collective growth. At the heart of a robust educational system lies science education, which equips learners with analytical thinking, problem-solving abilities, and a deeper understanding of the world around them. Science as a discipline not only helps students understand natural phenomena but also plays a critical role in driving innovation, technological advancement, and sustainable development (Aregbesola, 2023).Within the domain of science, biology stands out as a vital subject that provides insight into the structure, function, growth, origin, evolution, and distribution of living organisms. It is a foundational science that underpins various professional fields, including medicine, agriculture, biotechnology, and environmental science. As such, biology is considered an essential subject in the secondary school curriculum, especially in Nigeria, where it is a core subject in the Senior Secondary Certificate Examination (SSCE).

However, the teaching and learning of biology in many Nigerian secondary schools face several challenges, particularly in practical instruction. Traditional methods of instruction in biology, which are largely teacher-centered, rely heavily on chalk-and-talk approaches, rote memorization, and textbook-based learning. This method limits students' active participation and hinders the development of critical thinking and experimental skills. Practical work, which is central to understanding biological concepts, is often inadequately implemented due to lack of functional laboratories, insufficient instructional materials, and limited access to qualified teachers. According to Apochi and Okpaje (2022) innovative methods of teaching science are the modern instructional strategies employed by science teachers to communicate and facilitate interactions with their students and the subsequent outcome of the whole teaching-learning process.There are various specific innovative methods, this study targeted educational technology instruction as one of the instructional resources for learning in the biology classroom. This instruction plays a very important role in the teaching–learning process of biology (Ojelade, 2023; White and Bolker, 2017).

Advances in educational technology have introduced new ways of addressing some of the limitations of conventional instruction. One such innovation is the virtual laboratory. A virtual laboratory is a computer-based environment where students can perform simulated scientific experiments. It is designed to replicate the experience of working in a physical laboratory, allowing students to manipulate variables, observe outcomes, and interact with scientific apparatus in a safe and cost-effective way. Virtual laboratories provide an alternative platform that makes science learning more engaging, flexible, and accessible, particularly in settings where physical resources are limited. Chukwuemeka, et al (2025 and Makransky et al., (2016) submitted that students can learn at their own pace and revisit concepts as needed with the use of virtual laboratories instruction. Moreover, the interactive and multimedia features of virtual labs have been shown to enhance student motivation, comprehension, and retention of scientific knowledge. Students can learn the scientific concepts and gain new skills using virtual laboratory anytime and anywhere through laptops and smartphones. In a virtual laboratory, students will have the opportunity to make mistakes with minimal negative consequences compared to real laboratory, thus improving their confidence in carrying out real work.

In addition, a virtual laboratory can help students to conduct experiments virtually that were difficult to be conducted in a real laboratory due to lack of equipment, costly materials and/or dangerous situations. Furthermore, in virtual laboratories, students can observe visual representations of natural phenomena, collect data, make predictions, and write hypotheses, so that students will become actively involved in inquiry scientific processes (Ojelade, 2021 & Sypsas, 2019). Another important consideration in evaluating the impact of virtual laboratory instruction is gender. Gender disparities in science achievement have been documented across various educational contexts, often influenced by societal norms, teacher expectations, and access to learning resources (Ubom,et al 2023). While some studies suggest that male students tend to perform better in science subjects, others indicate that when given equal opportunities and supportive learning environments, female students perform just as well or even outperform their male counterparts (Ojelade, et al, 2018). Virtual laboratories may help bridge gender gaps by providing a non-threatening, individualized learning environment where students can experiment freely without fear of judgment or failure. .

Biology, as one of the core science subjects in the Nigerian secondary school curriculum, plays a critical role in equipping students with the foundational knowledge needed for various science-related careers. However, despite its importance, students' achievement in Biology, particularly in external examinations such as the West African Senior School Certificate Examination (WASSCE), has continued to decline over the years. In Kwali Area Council of the Federal Capital Territory (FCT), Abuja, this trend is no different, with many students exhibiting poor conceptual understanding and low achievement in Biology. This persistent underachievement has been attributed to several factors, among which the lack of effective practical experiences stands out prominently. Traditional laboratory settings, though essential, are often poorly equipped or entirely unavailable in many secondary schools within the area. As a result, students are deprived of the hands-on learning experiences necessary for mastering scientific concepts. Teachers, constrained by these limitations, resort to theoretical teaching methods that do not fully engage learners or foster critical thinking. This

situation not only affects students' performance but also their interest and motivation in learning Biology.

In response to these challenges, the integration of virtual laboratory instruction has been proposed as an innovative approach to complement or substitute physical laboratory experiences. Virtual laboratories provide simulated, interactive environments where students can conduct experiments, manipulate variables, and observe outcomes in ways that mirror real-life practicals. While this method has shown promise in various educational contexts globally, its effectiveness in improving Biology achievement among secondary school students in Kwali Area Council remains largely underexplored. Given the pressing need to enhance Biology education and improve student outcomes in the region, it becomes imperative to investigate whether virtual laboratory instruction can serve as a viable pedagogical strategy. This study, therefore, seeks to examine the effect of virtual laboratory instruction on secondary school students' achievement in Biology in Kwali Area Council, with the aim of providing empirical evidence to guide educational practice and policy in the area.

The purpose of this study is to investigate the effects of virtual laboratory on senior secondary school students' academic achievement and attitude towards Biology. Specifically, this study is set out to:

1. determine the effects of virtual laboratory and convention instructions on academic achievement of secondary school students taught Biology.
2. determine the different in achievement of male and female secondary school students' taught Biology.

The following research questions were raised to guide the study.

1. What are the differences in the achievement scores of secondary students exposed to virtual laboratory and those exposed to conventional instruction in Biology?
2. What is the difference in mean achievement scores of male and female students taught biology using virtual laboratory?

The following hypotheses were tested at 0.05 level of significance:

$H0_1$: There is no significant difference between mean academic achievement scores of secondary school students expose to virtual laboratory strategy and those taught using conventional method.

$H0_4$: There is no significant difference in the mean attitude score of male and female secondary students taught biology using virtual laboratory strategy.

Despite the benefits of virtual laboratory, there is continuous debate on the effect of using virtual experiments/laboratory in students' biology learning (Swan, 2015). Aleyadi (2019) showed that virtual laboratory had significant effects on students' knowledge, skills, attitudes, and achievement.This could be traceable to the methods and/or strategies used in teaching biology which is mainly the traditional method (face to face) strategy where the teacher perform experiment in the laboratory with the laboratory room full of students taking note (Mayowa, 2015). Several empirical studies have explored gender-related outcomes in virtual science instruction. For example, Yusuf and Afolabi (2019) investigated the use of computer-assisted instruction in teaching biology and found no statistically significant difference in the academic performance of male and female students exposed to the digital intervention. Similarly, Olumorin, Fakomogbon, and Yusuff (2018) reported that both genders benefited equally from e-learning tools when used effectively in science classrooms. These findings suggest that virtual laboratories may help level the playing field by eliminating some of the biases and barriers associated with traditional instructional methods. Gamtary and Gawu (2017), investigated the effects of virtual laboratory on the achievement levels and gender. The results showed that students exposed to virtual laboratory package in collaborative learning setting outperformed their counterparts in individualized setting without gender bias.

Nurul and Suyitno (2020) carried out a study on the effects of Virtual Laboratory Instructional Package on students' performance and gender. They found that students that were taught using virtual laboratory Instructional package performed significantly better than their counterparts who were exposed to the conventional method without gender bias. Based on the findings, it was recommended

that Government at all levels should endeavour to provide information and communication facilities like computer based instructional package in schools to teach chemistry and such must be made accessible to all students, to promote interactive and individualized learning among secondary school students. However, it is important to note that while virtual labs can reduce gender disparities, their effectiveness still depends on other contextual factors such as students' prior exposure to technology, digital literacy, school infrastructure, and teacher support. In under-resourced areas like Kwali Area Council in the Federal Capital Territory of Nigeria, these factors must be carefully considered. If male students have more prior experience with computers or mobile devices than female students due to cultural or socio-economic factors, they may initially adapt more quickly to virtual learning environments. Nonetheless, with adequate orientation and equitable access, female students can overcome these gaps and thrive in virtual laboratory-based biology instruction.

Meanwhile, traditional science classrooms have sometimes reinforced gender-based performance gaps, virtual laboratories present an opportunity to create a more balanced and inclusive learning environment. When thoughtfully implemented, these tools can promote gender equity in biology achievement by supporting active, personalized, and engaging learning experiences for all students. Teaching science in most of the developing countries do take cognizance of the conventional approach of teaching almost in all classes due to lack of instructional facilities. As such there are still gaps in our educational system and practices, especially in the area of biology practical.This study thus investigates not only the overall effectiveness of virtual labs in enhancing biology achievement but also whether there are any significant differences in the mean achievement scores of male and female students taught using this method.Yildirim, (2021) carried out a study on the effect of virtual laboratory applications on 8th Grade students' achievement in science lesson The study constituted of 62 students studying in the 8th grade of a secondary school in Antalya, Turkey. Mixed method design was used in the research. In the quantitative dimension of the study, the control group and the experimental group taught with virtual laboratory applications were compared in terms of achievement. The qualitative dimension of the study was composed of the data obtained from the interview forms conducted with the experimental group students after the application and the data obtained from the observation forms made during the application. Research results revealed that virtual laboratory applications increased the academic success of the experimental group students. On the other hand, it has been shown that virtual laboratory applications contribute to students' meaningful learning by enabling the concretization of abstract subjects, and that these applications positively support students' interest, excitement, and motivation towards the science course because they are found attractive.

Also, Aishurman, Al-Saree and Aishurfat (2021) worked on challenges that facing talented students in using virtual laboratories in Jordan. The sample of the study consisted of (102) students, whose were chosen intentionally from King Abdullah II schools for excellence in Mafraq during the second semester of the academic year 2019-2020. The descriptive and qualitative approach were used to answer research questions by using a three-part questionnaire (demographic data, challenges facing the use of virtual laboratories in King Abdullah II schools for excellence, and open-ended question for solutions to overcomes challenges that facing the use of virtual laboratories). Arithmetic averages, standard deviations, percentages, frequencies, and t-test were used for independent samples. The results showed that the degree of challenges that facing talented students in using virtual laboratories related to the whole dimensions of the questionnaire was an medium degree. In addition, the study showed that the degree of challenges of the virtual laboratory was high for both dimensions, the students and the quality of the software used, and it also appears that the degree of obstacles of the virtual laboratory was medium for the dimensions: the school environment, the curriculum and the teacher. Moreover. The study also identified the most important solutions to overcome the challenges that facing virtual laboratories in talented schools in Jordan.

Abdullahi, Daniel, Lasisi & Dania, (2020) investigated effects of virtual laboratory experiments on students' academic performance in physics practical. They made use of pre-test-post-test quasi experimental design with two levels of treatment and control group. The population of the study was senior secondary school two (SSS2). Purposeful sampling was used to obtain a sample of three co-educational senior secondary schools from a Local Government Area in Niger state, Nigeria for the

study. Intact classes were used. The instrument employed for the study were conventional lesson plans, an adopted computer simulation package for the Virtual Laboratory Experiments (VLE) and Researcher Made Test of Academic Performance in Physics Practical (RMTAPP). The data collected were analyzed using Descriptive Statistics, Analysis of Variance (ANOVA), Analysis of Covariance (ANCOVA) and t-test statistics. The result of the study revealed that, the teaching strategies have significant effects on SSS2 academic performance in Physics practical and that, a combination of VLE and Conventional method is the most effective, followed by VLE while the Conventional is the least effective. It reveals further that gender does not have significant effect on students' academic performance in Physics practical. The study therefore recommends that, Physics teachers should employ combination of VLE and Conventional teaching method to teach Physics practical and that, in schools with non-availability/inadequacy of science equipment, VLE method should be employed among others.

Method

The research design for the study was quasi-experimental design. The study made use of experimental and control group. The experimental group exposed students to the use of virtual laboratory instruction, while the control group was taught with conventional method Maithreyi, Kelly and Jee, (2020). The total population of the study comprised all the 30,977 SSII students offering Biology in Kwali Area Council, Federal Capital Territory. This category of students was targeted for the study because their experience in Biology was more than that of SS1 who had not yet gained much academic experience while SSIII students were left out of the study because they were busy preparing for external examination of WAEC and NECO. Purposeful sampling was used to select two schools; where one served as the control group and the other as the experimental group. Both schools are co-educational and have been in existence over ten years with qualified biology teachers for the SSII classes. The total number of students who participated in the study was 78 students: 40 students in the experimental group, they were 18 male and 22 female while that of control group was 38 with 15 male and 23 female respectively. The instruments that was used to collect data from the field was Biology Achievement Test (BAT). The instrument used in the study was drawn from WAEC questions based on topics taught during the treatment by the researcher and was used for both pretest and pre-test and post-test.

The BAT consisted of 30-items multiple choice objectives with four options (A,B,C and D), the students were expected to answer all the questions before and after the treatment in BAT. The Biology Achievement Test (BAT) was re-validated by twolecturers in Department of Science and Environmental Education (SEE) and two Biology experts from the selected pilot schools where necessary corrections were further made. These experts also compared the content of the topic covered in the study with what was measured by the BAT. The reliability of the BAT was determined by Kuder-Richardson formula-21 which gave value of the reliability to be 0.86 and was within the acceptable range in the literature and the instrument was therefore considered reliable for use in this study. Descriptive statistics of frequency, mean and standard deviation were used to calculate the research questions. While ANCOVA was used for the hypotheses at significant level of 0.05.

Results and Discussion

Research Questions One: What are the differences in the academic achievement scores of senior secondary students exposed to virtual laboratory and convention method in Biology?

Table 1: Mean and standard deviation of post-test scores of the experimental and control group of students' achievement

Group	N	Mean	SD	Mean Difference
Experimental	40	15.60	3.01	4.70
Control	38	10.90	3.79	

The mean scores and standard deviation of the experimental and control groups with respect to difference in post-test. It shows that the experimental group perform better than the control group with the mean of experimental group equal to 15.60 and that of the control group equal to 10.90 and mean difference of 4.70. It then implies that students taught biology using virtual laboratory have higher achievement than those taught using conventional method.

Research Questions Two: What is the difference in mean attitude score of male and female students taught biology using virtual laboratory?

Table 2: Mean and standard deviation of male and female students in experimental group on achievement

Group	N	Mean	SD	Mean Difference
Male	18	3.45	1.06	0.02
Female	22	3.43	1.08	

The mean scores and standard deviation of male and female students of experimental group. From the result obtained, the male students have mean scores of 3.45 as against the female students with mean scores of 3.43. The difference in mean achievement scores equal to 0.02. The implication is that there is no significant difference between mean achievement scores of male and female students taught biology using virtual laboratory.

$H0_1$:There is no significant difference between mean academic achievement scores of secondary school students expose to virtual laboratory strategy and those taught using conventional method.

Table 3: ANCOVA results of mean achievement score of the experimental and control groups

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	171. 360[a]	2	123.787	14.981	.000
Intercept	326.945	1	326.945	102.015	.001
Pre-test	.266	1	.266	.046	.851
Group	164.647	1	164.647	28.338	.000
Error	429.913	75	5.810		
Total	1264.350	78			
Corrected Total	701.243	77			

a. R Squared =.534 (Adjusted R Squared = .518)

Table 3 shows that there is a significant difference in mean achievement score of students exposed to virtual laboratory instructional strategy with [F(1, 75)= 28.338, p=.000]. Since the p-value is less than 0.05, hypothesis one was not accepted. Therefore, there is a significant difference between mean academic achievement scores of senior secondary school students expose to virtual laboratory and their counterpart who are not.

$H0_4$: There is no significant difference in the mean attitude score of male and female secondary students taught biology using virtual laboratory strategy.

Table 4: ANCOVA results of mean achievement score of male and female in experimental group

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	101.182[a]	2	43.787	13.215	.010
Intercept	276.157	1	276.157	51.240	.278
Pre-test	1.159	1	1.159	2.023	.351
Gender	124.510	1	124.510	14.132	.060
Error	291.241	37	8.810		
Total	1654.350	40			
Corrected Total	501.273	39			

a. R Squared =.325 (Adjusted R Squared = .310)

Table 4 shows that there is no significant difference between mean academic in achievement scores of male and female biology students' exposed to virtual laboratory instructional strategy with [F(1,37) =14.132, p=.060. Since p-value is higher than 0.05, hypothesis three is therefore accepted. Thus, there is no significant difference between mean academic achievement scores of male and female biology students' expose to virtual laboratory.

The result of the finding shows that there is a significant difference between mean academic achievement scores of senior secondary school students expose to virtual laboratory and their counterpart who are not. The finding of the study agreed with the findings of Yildirim, (2021) who discovered that virtual laboratory applications increased the academic success of the experimental group students. On the other hand, it has been shown that virtual laboratory applications contribute to students' meaningful learning by enabling the concretization of abstract subjects, and that these applications positively support students' interest, excitement, and motivation towards the science course because they are found attractive. Although this study did not find out students' interest, excitement and motivation but this study worked on achievement and motivation. Also, Yadah & Singh, (2019) whose found that low-achievers, average-achievers, and high-achievers' students of the experimental group outperform the control group. And they concluded from their study that the virtual laboratory strategy fosters the achievement of low-, average-, and high-achievers' students.

The result of this study confirmed that there is no significant difference between mean academic achievement scores of male and female biology students' expose to virtual laboratory. This corroborated the work of Gamtary and Gawu (2017), they investigated the effects of virtual laboratory on the achievement levels and gender. The results showed that students exposed to virtual laboratory package in collaborative learning setting outperformed their counterparts in individualized setting without gender bias. Nurul and Suyitno (2020) carried out a study on the effects of Virtual Laboratory Instructional Package on students' performance and gender. They found that students that were taught using virtual laboratory Instructional package performed significantly better than their counterparts who were exposed to the conventional method without gender bias. Based on the findings, it was recommended that Government at all levels should endeavour to provide information and communication facilities like computer based instructional package in schools to teach chemistry and such must be made accessible to all students, to promote interactive and individualized learning among secondary school students.

Conclusion and Recommendations

This study examined the **effect of virtual laboratory instruction on secondary school students' achievement in biology** within the Kwali Area Council of the Federal Capital Territory, Abuja. The investigation was guided by two core research questions: The findings of the study affirms the growing body of evidence that virtual laboratory instruction has a significant positive impact on students' academic achievement in biology. Students who were exposed to virtual laboratory instruction consistently outperformed their peers who received conventional, lecture-based

instruction. This difference in achievement suggests that virtual laboratories offer a more interactive, engaging, and student-centered learning environment, which promotes deeper understanding of biological concepts and fosters independent learning. Unlike conventional teaching methods, which often emphasize rote memorization and passive listening, virtual laboratories encourage exploration, visualization, and the application of scientific procedures in a simulated environment. This enhances students' cognitive processing and retention of biological information. The results therefore underscore the pedagogical value of virtual labs, especially in settings where physical laboratory facilities are inadequate or unavailable as is the case in many schools within Kwali Area Council.

The analysis also revealed that there was **no significant difference** in the achievement of male and female students who were taught biology using the virtual laboratory. This finding supports the argument that digital learning environments when designed and implemented equitably can promote gender balance in science education. Virtual laboratories provide a neutral and individualized space where students can experiment, make mistakes, and learn at their own pace, free from societal pressures or teacher biases. The implication is that virtual laboratory instruction not only enhances overall student achievement in biology but also contributes to narrowing the gender gap that has historically characterized performance in science subjects. By offering equal access to interactive content and practical simulations, virtual labs empower both male and female students to take active roles in their learning process and achieve academic success on an equal footing.

Based on the findings and conclusions drawn from this study, the following recommendations are proposed:

1. The Federal Ministry of Education, along with relevant state and local authorities, should encourage the integration of virtual laboratory platforms into the teaching of biology at the secondary school level. This should especially target schools in rural and under-resourced areas, such as Kwali Area Council, where access to physical laboratory equipment is limited.

2. Successful implementation of virtual laboratories requires that teachers be adequately trained in the use of educational technologies. Workshops, seminars, and continuous professional development programs should be organized to equip biology teachers with the skills necessary to incorporate virtual labs into their instructional practices effectively.

3. For virtual laboratory instruction to be effective, schools must be provided with the necessary technological infrastructure, including computers, tablets, internet access, and projectors. Government and private stakeholders should collaborate to ensure that schools are adequately equipped and supported with technical maintenance and ICT support services.

4. Educational policies and classroom practices should continue to promote gender inclusivity in science education. Since virtual laboratories have demonstrated the ability to minimize gender disparities in achievement, they should be leveraged as tools to support girls' active participation in STEM fields. Programs that encourage digital literacy among female students should be prioritized.

5. Continuous research should be undertaken to explore the long-term effects of virtual laboratory instruction on students' achievement, motivation, and interest in science. Comparative studies involving diverse geographic and socio-economic contexts would provide broader insights and help scale successful strategies across the education system.

In submission, virtual laboratory instruction presents a viable and impactful solution to many of the challenges currently faced in biology education in Nigeria. By fostering higher academic achievement and supporting gender equity in learning outcomes, virtual laboratories have the potential to transform science education and better prepare students for higher education and scientific careers in the 21st century.

References

1. Abdullahi, S. Daniel, E. Lasisi, D. & Dania, F. (2020). Evaluation of Science Teaching in Secondary Schools. Teaching of the Science. International Journal of Educational Science, 1(5), 109- 119.

2. Aishurman, D. Al-Saree, F. S. and Aishurfat, K. (2021). Exploring Factors Affecting Performance in Biology at Selected High Schools in Lesotho. *Mediterranean Journal of Social Sciences*, Publishing, Rome-Italy.ISSN 2139-2145.
3. Aleyadi, J. (2019). Effects of Virtual Laboratory and Demonstration on Secondary School Biology Students Achievement. *Journal of the Science Teachers' Association of Nigeria* 38 (1 and 2) 58-63.
4. Apochi, M. A. & Okpaje, O. J. (2022). Survey of science teachers' use of innovative methods of teaching. *International Journal of Research and Innovation in Social Science (IJRISS)*, *6*(6), 138 – 142.
5. Aregbesola, B.G. (2023). Effects of Integrated Group Based Mastering Learning Model on Students' Achievement in Rate of Reactions, AMAC Area Council, FCT-Abuja Nigeria. Best Journal of Innovation in Science, Research and Development, 2,(8), 112-120. Retrieved from http://www.bjisrd.com/index.php/bjisrd/article/view/525.
6. Bruner, J. S. (1966). *Toward a theory of instruction*. Harvard University Press.
7. Chukwuemeka, E.J. & Aregbesola, B.G. (2025). Secondary School Teachers' Proficiency in Integrating Technology within their Subject-Matter Contexts in Nigeria. Ilorin Journal of Education (IJE). 45, 2. https://ije.unilorinedu.sch.ng/index.php/ije/article/view/245
8. Deslauriers, F.O. and Wieman, D.L. (2011). Evaluation of the Methodology Aspect of Science Teacher Education Curriculum in Nigeria. *Pakistan Journal of Social Sciences* 17 (2) 170-176.
9. Federal Ministry of Education (2013). *Senior Secondary School Curriculum Biology*. Corrected Version. 6th edition of National Policy on Education.
10. Gamtary, N.& Gawu, F. (2017). Research Framework: A Literature Review and Future Research Directions with Virtual Laboratory. Published in 14th IOPMA Conference, 23- 24 July.
11. Ma, M. & Nickerson, A. (2016). Rewarding better teacher? Performance related pay in schools. *Journal of Educational management and administrative* 5(3): 46- 53.
12. Maithreyi, D., Kelly, J., and Jee, S. (2020). Technology and Science Education: Starting points, research programmes and Trends. Int. J. Science Educ., 25(6): 727.
13. Mayowa, A. (2015). Effect of a virtual chemistry laboratory on students' achievement. *Educational Technology & Society*, 16(1), 159–170.!
14. Mekonnen, K. (2014). Why Minimal Guidance during Instruction Doesn't Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experimental and Virtual Teaching. *Educational Psychologist* 41 (2) 75-86.
15. Nicholas, D. (2012). Effects of Collaboration and Modelling on Reasoning and Performance in Biology. *Grin Verlag GmbH [online]*. *Availaboratoryle: file/effects–of–Collaboration–and–modelling–on–reasoning–and–performance.*
16. Nurul, M. & Suyitno, U. (2020). Virtual simulations as preparation for lab exercises: Assessing learning of key laboratory skills in microbiology and improvement of learning outcomes. Journal of Science Education.11(6),
17. Ojelade, I.A Aregbesola, B.G. & Haastrup D.T. (2023). Teaching Science Education in Nigeria University for Innovation, Group Collaboration, Job Creation, Accessing Bank Loans and Creativity Society for Young Inventors. International Journal on Orange Technology. 5 (10), 26-43. https://journals.researchparks.org/index.php/IJOT.
18. Ojelade, I.A., C.G. Ekpo & B. G. Aregbesola (2021). Effects of 3-Dimensional computer simulation on secondary school students' academic achievement in chemistry. Journal of Science and Science Education, 5(2), 18-25.

19. Ojelade, I.A. & Aregbesola, B.G. (2018). Teacher's Experience and Students' Academic Performance in Secondary School Chemistry Final Examination in Ido LGA of Ibadan Nigeria. The Researchers: Journal of Contemporary Educational Research. www.researchersjournalorg. 1-9, 3(2).39-49

20. Olumorin, C. O., Fakomogbon, M. A., & Yusuff, A. A. (2018). E-learning and academic performance of undergraduates in Nigeria: Evidence from a public university. *Journal of Emerging Trends in Educational Research and Policy Studies (JETERAPS)*, 9(4), 182–187.

21. Sahin, M., & Yilmaz, H. B. (2020). The effect of virtual laboratories on students' science achievement and attitudes: A meta-analysis study. *Journal of Science Education and Technology*, 29(4), 458–473. https://doi.org/10.1007/s10956-020-09831-w

22. Stoet, G., & Geary, D. C. (2017). Sex differences in mathematics and reading achievement are inversely related: Within- and across-nation assessment of 10 years of PISA data. *PLOS ONE*, 8(3), e57988. https://doi.org/10.1371/journal.pone.0057988

23. Sullivan, T. (2017). *The Teaching of Science 21st Century Perspective*. U.S.A: National Science Teachers Association Press.

24. Swan, H. (2015). Comparison of Virtual Laboratory and Modelling Instruction in a High School Physics Classroom. *Unpublished M. SC Thesis*, School of Technology Brigham Young University.

25. Sypsas, K. (2019). The Effects of the 5E Learning Cycle Model on Students' Understanding of Force and Motion concepts. *Unpublished M. Ed Thesis* University of Central Florida, Orlando: Florida.

26. Ubom, A.E.B, Ojelade, I.A., & Aregbesola, B.G. (2023). Emerging Technologies, Security Issues and innovations in Tertiary Education. *Abuja Journal of Education, 11(1), 60-76.*

27. White, K. P., & Bolker, F.I. (2017). The Relative Effects of Virtual and Lecture Methods. The Performance of High and Low Achievers in Senior Secondary School Biology. *Journal of Science Teachers Association, New York*. 82 (12), 59-64.

28. Yildirim, G. (2021). *The Psychology of Intelligence in Leaning Biology*. London : Routledge and Kegan Paul.

29. Yusuf, M. O., & Afolabi, A. O. (2018). Effects of computer-assisted instruction (CAI) on secondary school students' performance in biology. *The Turkish Online Journal of Educational Technology*, 9(1), 62–69.