Faculty of Natural and Applied Sciences Journal of Applied and Physical Sciences
Print ISSN: 3026-9857
www.fnasjournals.com
Volume 2; Issue 1; September 2024; Page No. 37-45.

Effects of Virtual Laboratory and Gender on the Learning Outcomes of Undergraduate Physics Students in Ohm's Law Verification

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Abstract
This study examined virtual laboratory effect and gender on the verification of ohm's law and undergraduate physics students' performance and retention in Ignatius Ajuru University of Education, Port Harcourt. Quasi experimental of the type, pretest-posttest, post-posttest control group design was adopted for this study. The population of the study comprised all year 2 undergraduate physics students of Ignatius Ajuru University of Education, numbering one hundred and eight (108). "Simple Random Sampling Technique was employed to get a sample size of seventy-two (72). Four research questions and four hypotheses were formulated to guide this study. An experimental group and a control group were used for the study. The experimental group was taught practical physics using a virtual laboratory (Circuit lab software) while the control group was taught using the hands-on laboratory. The instrument used for this study is a test titled "Physics Practical Test on the Verification of Ohm's Law (PPTVOL)". A reliability index of 0.72 was obtained for (PPTVOL) using the test-retest method. Data were analyzed using mean and standard deviation to answer the research questions while a t-test was used to test the hypotheses at 0.05 level of significance." The findings of the study revealed that the use of a virtual laboratory in practical physics does not have a significant effect on gender as regards performance and retention. It was also found that the use of hands-on laboratory does not have a significant effect on gender as regards performance and retention. This study recommends that physics lecturers should use virtual laboratories for teaching practicals.

Keywords: Virtual Laboratory, Learning Outcomes, Physics Students, Ohm's Law Verification, Gender Differences

Introduction

The developing nations to which our country Nigeria belongs are greatly battling with gender inequality issues in the educational sector. Gender inequality in performance in physics as found by Ojediran et al. (2014) in their study poses a great challenge to the economy of any nation. Physics we know is the core of all technology which invariably affects the economy of any nation positively. Raju (2017) noted that the economic empowerment of women is often recognized as a crucial method for advancing gender equality, alleviating poverty, and enhancing the well-being of women, children, and society as a whole. How is this possible amidst scholars' reports that females are backwards in performance in science-related subjects and courses? Corroborating this, Aniodoh and Eze (2014) stated that gender discrimination has resulted in disparities between men and girls in science and technology courses, with females falling behind. According to Shedrack and Nduudee (2023), this presents a significant obstacle for our country since there may not be a sufficient number of workers in the future due to female under-representation as a result of poor performance in physics, to make a substantial contribution to its economic and technological development. Nnaka and Ezekannagha (2013) observed that there is a widespread belief that males possess inherent superiority over females in the fields of science and technology. Little wonder, we hardly see females in the midst of men who are into engineering jobs of any type in society. Okeke (2009) as cited in Nnaka and Ezekannagha (2013) reported that this notion adversely affects the involvement of women in science and technology education and careers. Aniodoh and Eze (2014) stated that gender discrimination has resulted in disparities between boys and girls in science and technology courses, with females falling behind. However, some researchers, Musa et al. (2024) study, reported that there is no noteworthy disparity in performance between genders in scientific disciplines. Improved academic performance is strongly correlated

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with increased student retention. There is therefore the need for teachers to employ teaching strategies that will boost the retentive memories of students irrespective of gender.

Retention, as defined by the Longman Dictionary of Contemporary English (LDOCE), refers to the cognitive capacity to maintain information in one's memory. In their view, Hauwau and Hauwa (2018) stated in their work that retention is a unique mental capacity to retain information that has been previously learned through the teaching and learning process which can be recalled by students after a later time. Okeke (2011) observed that gender has a substantial impact on the average retention scores of science students. Omwirhiren (2015) unveiled that males have superior recall abilities compared to females, a finding that supports his argument. Achor and Gbadamosi (2020) also found that male students had superior memory in physics compared to their female counterparts. These reports have supported the fact that males are better than females in performance in the sciences since the information that a student retains is what he or she can recall during an examination. Little wonder, scholars are advocating for teaching methods that will help improve student retention and performance irrespective of gender for science instruction, especially in physics.

The laboratory method of teaching has been greatly commended by various scholars. According to Atomatofa (2015), the objective of teachers doing laboratory activities with students is to facilitate learning and ensure the retention of information. Aniaku (2012) stated that hands-on laboratory applications are teaching methods that focus on activities and encourage active participation of students in classroom activities. Amadalo et al. (2012) observed in their study that the "laboratory method of teaching creates motivation and interest for learning physics and that students tend to learn better in activity-based courses where they can manipulate equipment and apparatus to gain insight into the content. They added that, if practised in the right manner from the early secondary school period, critical thinking skills can be attained from practical work in physics. They further pointed to the fact that practical work puts the students at the centre of learning where they can participate in, rather be told about physics and that, in this way, the desire and eagerness to know more about what the subject can offer is developed." Practicals as we know, are carried out in the laboratories. The learning environment in the laboratory is conducive to pedagogical practices and collaborative education. This indicates that in order for science to be taught in a thorough and efficient manner, laboratories must be an essential component of the scientific curriculum. The majority of people often refer to the hands-on (conventional) laboratory as the guided inquiry approach. The guided inquiry technique involves providing students with limited knowledge and then allowing them to proceed with the practical aspect independently. According to Aniaku (2012), inquiry techniques are a great way to get students involved in their own learning and the process of teaching. Her position is that pupils' understanding and performance in school are both improved when they take an active role in their own education. However, Doucette and Singh (2024) observed that gender inequality poses a serious problem for physics laboratory education. In the pursuit of their study, they found that previous research revealed that a major problem of most gender differences noticed in physics laboratories is the masculine nature of physics. Continuously, they noted that students, particularly those from historically underrepresented groups like women, may not have the opportunity to develop the abilities that could negatively impact their academic performance and potential career paths if there is a lack of equality and inclusiveness in traditional physics lab learning environments. This may have prompted Rosen and Kelly's (2020) study which found that there is no gender bias between men and women in online labs. An online laboratory is synonymous with a virtual laboratory.

Oluwasegun and Olabode (2020) defined a virtual laboratory as a simulated learning environment designed to enhance students' laboratory abilities by replicating actual laboratory experiences. In essence, it involves doing scientific experiments digitally on a computer screen. Umukozi et al. (2023) reported in their work that the use of virtual labs in teaching physics enhances the academic performance of students in Rwanda's senior secondary schools. In another related study, Gambari et al. (2013) revealed in their study that gender does not have a significant effect on students' academic performance in physics practicals when taught in a virtual laboratory. Buttressing the merits of the virtual laboratory, Hendron (2014) in Theodore et al. (2016) found that the ability to have a good retentive memory or recognize information after learning is improved when it is presented using both visual and spoken methods. The virtual laboratory may accomplish this goal since it has both characteristics. Moreover, many educational theorists have said times without numbers learning is maximized when attached to visuals. The employment of virtual labs in scientific education, particularly in the field of physics of truth, has tremendous potential. It is in light of the explanations stated above that the researchers seek to investigate on virtual laboratory effect and gender on the verification of Ohm's law and undergraduate physics students' performance and retention in Ignatius Ajuru University of Education, Port Harcourt.

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Statement of the Problem

Poor performance among undergraduate physics students poses an enormous threat to any nation. Some scholars asserted that females make up a larger proportion of individuals who perform below the expected level in physics. On the contrary, some others didn't agree with it. Be that as it may, should we as educators focus on this argument? Certainly not. To meet the needs of our nation, it is necessary to ensure that both genders are provided with equal opportunities in the educational sector, to get enough workforce capable of addressing our daily issues in the future. We should therefore seek innovative teaching methods that are not gender bias to be able to provide a solution to this problem? Application of the virtual laboratory in the teaching of physics in our higher institutions may fill the gap between males and females as regards performance and retention.

Research Questions

The following research questions guided the study:

i) What is the difference between the mean performance scores of male and female students in practical physics exposed to virtual laboratories (circuit lab software)?

ii) What is the difference between the mean retention scores of male and female students in practical physics exposed to virtual laboratory (circuit lab software)?

iii) What is the difference between the mean performance scores of male and female students in practical physics exposed to hands-on laboratory?

iv) What is the difference between the mean retention scores of male and female students in practical physics exposed to hands-on laboratory?"

Hypotheses

This study was guided by the following hypotheses:

HO_1: There is no significant difference in the mean performance scores of male and female students in practical physics exposed to virtual laboratory (circuit lab software).

HO_2: There is no significant difference in the mean retention scores of male and female students in practical physics exposed to virtual laboratory (circuit lab software).

HO_3: There is no significant difference in the mean performance scores of male and female students in practical physics exposed to hands-on laboratory.

HO_4: There is no significant difference in the mean retention scores of male and female students in practical physics exposed to hands-on laboratory"

Methodology

The design for the study was quasi-experimental of the type, pretest-posttest, post-posttest control group design. A simple random sampling technique was employed to get a sample size of seventy-two (72) undergraduate year two physics students. Thirty-six (36) students were randomly assigned to each of the groups (experimental and control)." The researchers got each of the numbers in the groups by providing a container which contained pieces of paper written capital A and B on each of them. Students were asked to pick in turns after which all As and Bs were separated from each group. In each of the groups, the males were also separated from the females to get their numbers. This gave a total of 41 males and 31 females. The instrument for this study is the Physics Practical Test on the Verification of Ohm's Law (PPTVOL) which was adopted from the Physics Writers Series practical textbook. The test items consist of practical physics questions on the verification of Ohm's law. There were four (4) questions to answer in all. Question 1 tested students' ability to handle all the needed apparatus to carry out the practical which will enable them to fill the table. Question 2 of the text item tested students' ability to plot a graph e.g plotting the graph of current (I) against voltage (V) without which the slope of the graph cannot be calculated. Question 3 tested students' ability to solve mathematical problems (slope) and interpretation of data skills. For instance, was Ohm's law obeyed when looking at the table and the graph plotted? Which states that at a constant temperature, the current flowing through a conductor is directly proportional to the potential difference applied to the ends of a conductor. Question 4 tested students' concluding skill i.e. outlining precautions to ensure accurate results. Each question was awarded 5 marks giving a total of 20 marks.

Two lesson notes (Virtual laboratory and hands-on laboratory on the verification of Ohm's law) were prepared by the researchers. The experimental group lesson note was written based on the virtual laboratory method while the control group lesson note was written based on the hands-on (guided inquiry) laboratory method. For students who were exposed to circuit lab software i.e. those in the experimental group, the mode of instruction was done virtually through simulation. CircuitLab software developed by Robbins (2021) was adopted for the study. Also, the researchers with the help of two computer technologists taught the students how to download "CircuitLab software" an application software on their individual computers via the internet i.e. those in the experimental group. This application is already on the net and requires the users or students to download using the site "circuitlab.com/cu5584wxrenxw". Each student was assigned to one desktop in the computer classroom. The following instructions were followed: Click the circuit, then click "Simulate," and click "Run DC Solver". This will show the calculated voltage. Next, click Run DC Sweep. The circuit lab simulator will instantly plot a graph with the current setting on the x-axis and the resulting voltage on the y-axis. The researchers taught the students the commands to follow to run the program which eventually ended with a graph of current (I) against voltage (V) showing on the screen of their individual computers. After which graphs were printed out. For the control group, all the equipment for the verification of Ohm's law experiment was released to the students. The guided inquiry laboratory method was applied by which minimal information was given to the students by the teachers who are the researchers after which students are left to go ahead with the lesson. The researchers assisted by two physics laboratory technologists of IAUE taught the control group.

The difference between the two groups was that students in the experimental group were taught and tested via circuit lab software while the control group was taught and tested through literal handling of the various apparatus (hands-on laboratory). Thus, all the subjects were exposed to different methods of instruction. This implies that any difference observed in their achievement in practical physics will be attributed to the medium of presenting the instruction. Before treatments for the two groups, PPTVOL was administered as a pre-test. Three hours outside of their lecture days were fixed for each of the groups for two different days in two weeks to administer the treatment. After treatment, PPTVOL was re-administered as a post-test to all the two groups. To test for retention the post- post-test was re-administered to the two groups after two weeks of administering the post-test. The researchers were able to achieve this with ease because of the support from lab technologists and computer technologists.
"Statistical mean and standard deviation were used to answer the research questions while t-test was used to answer the hypotheses at 0.05 level of significance."

Results

Table 1: Mean and Standard Deviation of the Pretest and Post-test Mean Scores of Male and Female Students in Virtual Laboratory (VL)

Group	Sex	N	Pretest Mean	SD	Post-test mean	SD	Mean difference
VL	Male	20	10.55	2.373	15.65	1.309	5.10
	Female	16	10.44	2.529	14.88	1.708	4.44

Table 1 shows "that the pre-tests mean and SD for male was 10.55 and 2.373 while that of female was 10.44 and 2.259 respectively. A look at the means of the pre-test for the two groups revealed that male students scored a little higher than the females. Similarly, the post-test mean and SD for males were 15.65 and 1.309 while that of the females was 14.88 and 1.708 respectively. Furthermore, the mean gain on the basis of the differences between the test scores and post- test scores indicated 5.10 for male and 4.44 for female as shown on Table 1. Consequently, a cursory look at the post-test mean scores for the male and female showed that males (15.65) and females (14.88) improved greatly in their performance. Hence, based on their performance scores, the difference between the mean performance scores of male and female students is 0.67."

Table 2: Mean and Standard Deviation of the Post-test Mean Scores of Male and Female Students' in Virtual Laboratory

Group	Sex	N	Post test $\bar{x}$	SD	Retention $\bar{x}$	SD	Mean difference
VL	Male	20	15.65	1.309	16.50	1.277	0.85
	Female	16	14.88	1.708	15.44	1.365	0.56

The results on Table 2, show that for the males in the virtual laboratory group, the post-test means and SD are15.65 and 1.309 respectively while the retention mean and SD are 16.50 and 1.277 respectively. Similarly, for the females, the post-test mean and SD are 14.88 and 1.708 respectively while the retention mean and SD are 15.44 and 1.365 respectively. These values show that both male and female students improved greatly in their retention scores. The result is that male and female students differ in their mean retention scores by 1.06 value.

Table 3: Mean and Standard Deviation of the Pretest and Post-test Mean Scores of Male and Female Students in Hands-on Laboratory (HL)

Group	Sex	N	Pretest Mean	SD	Post-test mean	SD	Mean difference
HL	Male	21	10.48	2.421	11.76	2.278	1.28
	Female	15	10.60	1.682	11.80	2.274	1.20

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Table 3 shows that the pre-test mean and SD for males were 10.48 and 2.421 while for females were 10.60 and 1.682 respectively. A look at the means of the pre-test for the two groups revealed that female students in scored a bit higher on the pretest than the males. Similarly, the post-test mean and SD for males was 11.76 and 2.278 while that of the females was 11.80 and 2.274 respectively. Furthermore, the mean gain on the basis of the differences between the pre-test scores and post test scores of indicated 1.28 for male and 1.20 for female as shown on Table 3. Consequently, a cursory look at the post test means scores for the male and female shows that males (11.76) and females (11.80) are almost at the same level of performance. Hence, based on their performance scores, the difference in the mean performance scores between male and female students is 0.04."

Table 4; Mean and Standard Deviation of the Post-posttest Mean Scores of Male and Female Students in Hands-on Laboratory

Group	Sex		Post-test		Retention		Mean
		N	$\bar{x}$	SD	$\bar{x}$	SD	difference
HL	Male	21	11.76	2.278	11.62	2.179	-0.14
	Female	15	11.80	2.274	11.80	2.651	0.00

The results in Table 4, show that for the males in the HL group, the post-test means and SD are 11.76 and 2.278 respectively while the retention mean and SD are 11.62 and 2.179 respectively. Similarly, for the females, the post-test mean and SD are 11.80 and 2.274 respectively while the retention mean and SD are 11.80 and 2.651 respectively. These values show that both male and female students did not improve in their retention scores. The result is that male and female students differ in their mean retention scores by 0.18 value.

Hypothesis 1: There is no significant difference in the mean performance scores of male and female students in practical physics exposed to virtual laboratory (circuit lab software).

Table 5: A t-test Analysis of Gender Difference in the Post Test Mean Scores of Physics Students Exposed to Virtual Laboratory (VL)

Group	Gender	N	X	SD	df	t-cal	Sig(0.05)	Decision
VL	Male	20	15.65	1.309				
					34	1.542	0.488	NS
	Female	16	14.88	1.708				

NS = Not significant, p> 0.05 level of significance

Table 5 indicates that the t-value of 1.542 for male and female students in the VL group is not statistically significant at the 0.05 level. Consequently, the null hypothesis was upheld for the VL group. This implies that there is no notable difference in the average performance scores between male and female students taught practical physics using the Virtual Laboratory." This means that there is no gender bias about students' performance when students are exposed to virtual laboratories.

Hypothesis 2: There is no significant difference in the mean retention scores of male and female students in practical physics exposed to virtual laboratory (circuit lab software)

Table 6: A t-test Analysis of Gender Difference in the Post-post Test Mean Scores of Physics Students Exposed to Virtual Laboratory (VL)

Group	Gender	N	X	SD	df	t-cal	Sig(0.05)	Decision
VL	Male	20	16.50	1.277				
					34	2.409	.643	NS
	Female	16	15.44	1.365				

NS = Not significant, p > 0.05 level of significance

Similarly, the calculated t-value (2.409) for male and female students in the CM group is not significant at the 0.05 level. Consequently, the null hypothesis was accepted, indicating that there is no significant difference in the mean retention scores of male and female students taught practical Physics using a virtual laboratory. Meaning that there is no gender bias in relation to students' retention when students are exposed to virtual laboratory.

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Hypothesis 3: There is no significant difference in the mean performance scores of male and female students in practical physics exposed to hands-on laboratory.

Table 7: A t-test Analysis of Gender Difference in the Post Test Mean Scores of Undergraduate Physics Students Exposed to Hands-on Laboratory

Group	Gender	N	X	SD	df	t-cal	Sig(0.05)	Decision
HL	Male	21	11.76	2.278	34	-.049	.541	NS
	Female	15	11.80	2.274				

NS = Not significant, p > 0.05 level of significance

Table 7 indicates that the t-value calculated for male and female students in the HL group is -0.049, which is not statistically significant at the 0.05 level. Consequently, the null hypothesis was accepted for the HL group. The findings suggest that there is no significant difference in the average performance scores of male and female students who were taught practical physics using hands-on laboratory methods. Meaning that there is no gender bias in relation to students' performance when students are exposed to hands-on laboratory.

Hypothesis 4: There is no significant difference in the mean retention scores of male and female students in practical physics exposed to hands-on laboratory.

Table 8: A t-test Analysis of Gender Difference in the Post-posttest Mean Scores of Undergraduate Physics Students Exposed to the Hands-on Laboratory (HL) Method

Groups	Gender	N	X	SD	df	t-cal	Sig(0.05)	Decision
HL	Male	21	11.62	2.179	34	-.224	.355	NS
	Female	15	11.80	2.651				

NS = Not significant, p > 0.05 level of significance

Similarly, the calculated t-value (-0.224) for male and female students in the HL group is not significant at the 0.05 level. As a result, the null hypothesis was accepted. This indicates that there is no significant difference in the mean retention scores between male and female students in practical physics when exposed to hands-on laboratory activities. Meaning that there is no gender bias in relation to students' retention when students are exposed to hands-on laboratory.

Discussion

To accomplish the objectives of this research, the authors formulated four hypotheses. The outcomes of the study are discussed in the following sections. The analysis of the first hypothesis, as displayed in Table 5, revealed no significant difference in the average performance scores between male and female students who were taught using a virtual laboratory. These findings align with the research conducted by Gunawan et al. (2020), which also demonstrated that gender does not significantly impact students' academic performance when utilizing a virtual laboratory. This cannot be unconnected with the attributes of a virtual laboratory which among others is that such experiments are accompanied by image, movement and sound. The males and females have equal opportunities to relearn via watching the subject matter online even outside the classroom. However, the finding of this study does not align with that of Skaalvik and Skaalvik (2004) cited in Gunawan et al. (2018) whose study found that male students have better performance than their counterparts. This study also negates that of Gunawan et al. (2018) and Liwhuliwhue et al. (2023) whose studies found a significant difference between the performance of male and female physics students in favour of the females.

Additionally, the findings related to hypothesis 2, presented in Table 6, demonstrated that there was no significant difference in the average retention scores between male and female students who were taught using a virtual laboratory. This outcome is consistent with the study by Gambari et al. (2013), which showed that the use of virtual laboratories enhances retention for students regardless of gender. Similarly, research by Lux (2002) and Kara (2008), both referenced in Gambari et al. (2013), also found no gender disparity in retention scores among students using virtual laboratory tools. The researchers think that this is so because of the attributes of a virtual

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laboratory which among others include studying at any time and anywhere. Both male and female students have the privilege of relearning what they have been taught as many times as they want, even without the presence of the teacher and when something is reinforced, retention is inevitable. Nonetheless, this study differs from the earlier findings of Kost et al. (2009) and Anagbogu and Ezeliora (2007) both cited in Gambari et al. (2013) whose studies reported gender bias. Moreover, the findings from hypothesis three, as presented in Table 7, revealed no significant difference in the average performance scores between male and female students who were taught using hands-on laboratory methods. This outcome aligns with the conclusions of Uzezi and Zainab (2017) and Ekomaye (2019), both of whom found that gender does not significantly impact students' academic achievement when exposed to chemistry through hands-on (guided inquiry) laboratory experiments. Similarly, Ogwuadu's (2010) study also found no significant difference in performance between boys and girls engaged in hands-on (guided inquiry) laboratory activities. Ogwuadu (2010) emphasized that active student participation in the teaching and learning process enhances knowledge acquisition and academic performance, regardless of gender. Conversely, this study's findings contrast with those of Amadalo et al. (2016), who reported that boys achieved higher mean scores than girls when engaging in hands-on laboratory (practical work) activities.

The findings related to hypothesis 4, as presented in Table 8, revealed no significant difference in the average retention scores between male and female students who were taught using hands-on laboratory activities. The researchers suggested that this outcome could be due to the characteristics of the hands-on laboratory approach, which emphasizes guided inquiry. Ogwuadu (2010) noted that inquiry-based methods are activity-focused and promote active student engagement in the learning process. Both the males and females were actively involved in the learning which is a potential for retention of knowledge. However, this result contradicts that of Chibabi et al. (2021) whose study showed that there is a significant difference in the mean retention scores of male and female senior secondary school students in Biology after exposure to hands-on laboratory methods of teaching. The finding of this study also disagrees with that of Ibe (2006) study on gender and teaching methods on science process skills acquisition which revealed that boys have better retention than their female counterparts. He attributed the gender gap in retention which is in favor of the boys among co-educational schools to issues like intense sex role stereotyping and apparent male domination of science learning activities.

Conclusion

Virtual and hands-on laboratory methods of teaching are not gender bias on the basis that both males and females in each group improved in their performance and retentive capacity in physics. Furthermore, this work have reiterated the fact that the twenty-first century is filled with innovations in teaching pedagogies as a result of the internet that should influence today's undergraduates and university teachers among which is the virtual laboratory.

Recommendations

Based on the findings of this study, the researchers made the following recommendations:

1. Curriculum planners should organize workshops and seminars to train science lecturers on the use of virtual laboratories .
2. The government should make it a duty to support our universities with regular power supply because it is very indispensable in the execution of a virtual laboratory.
3. Physics undergraduate students in universities should use virtual laboratories as part of their learning since it has been found that what we repetitively do enhances performance and retention.
4. Physics lecturers should use virtual laboratories for teaching practicals having found that it improved performance and retention irrespective of gender.
5. Physics teachers should continue with their use of hands-on laboratory for teaching practicals having found that it is not gender bias.

References

Achor, E.E., & Gbadamosi, B.O. (2020). Raising the achievement and retention levels of secondary school students in physics through brain-based learning strategy in Taraba State, Nigeria. *BSU Journal of Science, Mathematics and Computer Education, 1* (2), 1-13.

Amadalo, M. M., Ocholla, A.A., & Sakwa, T. W. (2016). Physics practical work and its influence on students' academic achievement. *Journal of Education and Practice,7* (28), 129 – 134.

Aniaku, O.L. (2012). Effects of guided and unguided inquiry teaching methods on secondary school students' achievement and interest in biology in Enugu State. A published M.ed work.

Aniodoh, H.C.O., & Eze, G.L. (2014). Enhancing girls' participation in science through feminist pedagogical techniques: A panacea for gender-gap in science and technology classrooms. STAN proceedings, 304 – 311.

Cite this article as:
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Atomatofa, R. (2016). Relationship between communication-type and laboratory behavior of Basic science students during practical sessions in Nigeria. STAN Proceedings, pp 88 – 97.

Chibabi, A.A., Umoru, S.E., Onah, D.O., & Itodo, E.E. (2021). Effect of laboratory method on students achievement and retention in senior secondary schools in Biology in Kogi east senatorial zone. *Journal of Research and Method in Education, 8*(6), 31 – 39.

Doucette, D., & Singh, C. (2024). Gender equity in physics labs: A review.arXiv:2403.01522v1 [physics.ed-ph]. https://arxiv.org/html/2403.01522v1 .

Ekomaye, D.G. (2019). Effect of guided inquiry teaching method on secondary school students' achievement in light and sound waves in Abuja, Nigeria. *Journal of Education and e-Learning Research, 6* (2), 82-87.

Gambari, A. I., Falode, O.C., Fagbemi, P.O., & Idris, B. (2013). Efficacy of virtual laboratory on the achievement and attitude of secondary school students in Physics practical. *Research in Curriculum Studies, 9* (1).9-20.

Gunawan, G., Suranti,Y. M. N., Nisrina, N., Herayanti, L., & Rahmatiah, R. (2018). The effect of virtual lab and gender toward students' creativity of physics in senior high school. *IOP Conf. Series: Journal of Physics: Conf. Series* 1108 012043 doi :10.1088/1742-6596/1108/1/012043 1-7.

Gunawan, G., Susilawati, Dewi, S. M., Herayanti, L., Lestari, P. A. S., & Fathoroni, F. (2020). Gender Influence on Students Creativity in Physics Learning with Virtual Laboratory. *Journal of Physics: Conference Series* 1471 (1), p. 012036. https://doi.org/10.1088/1742- 6596/1471/1/012036

Hauwau, A., & Hauwa,U. D. (2018). Effect of real and improvised materials on retention and performance of female students in secondary schools basic science in Kaduna metropolis, Kaduna State Nigeria. *Knowledge Review Volume, 37* (1), 130 – 137.

Ibe, E. (2006). Effects of gender and teaching methods on science process skills acquisition among senior secondary students. *International Journal of Educational Research, 1* (1), 141 – 147.

Longman Dictionary of Contemporary English (LDOCE).(2016).6th Edition. Pearson Publishing Company, London.

Liwhuliwhue, A., U., Ofoegbu, O. T., & Asogwa, U. D. (2023). Effect of physics education technology (PHET) virtual laboratory experiment simulation on students' academic performance in practical physics in Ogoja education zone. *African Journal of Science, Technology and Mathematics Education* (*AJSTME), 9* (5), 330-336, https://www.ajstme.com.ng ISSN: 2251-0141 (Print), 2971-623 (Online).

Musa, G., Shehu, B. S., Ibrahim, A.S., Harazimi, C.A., & Ahmad, M .I. (2024). Effects of Gagne's nine events of instruction on biology students academic performance in Tarauni, Kano State. *Ilorin Journal of Education (IJE), 44* (2), 92- 105.

Nnaka, C.V., & Ezekannagha, G.N. (2013). Society's current attitude towards women in science and technology based artisan jobs as a factor in mainstreaming girls into STM education. STAN Proceedings, 303 -309.

Ogwuadu, O.R. (2010). The effect of guided inquiry and lecture methods on students' academic achievement in biology: a case study of Yola North Local Government Area of Adamawa state. *Knowledge Review*, *21* (1), 107 -114.

Ojediran, I. A., Oludipe, D.I.R., & Ehindero, O. J. (2014). Impact of laboratory-based instructional intervention on the learning outcomes of low performing senior secondary students in physics. http://creativecommons.org/licenses/by/4.0/

Okeke, O. J. (2011). Effect of mind-mapping teaching strategy on students' achievement, interest and retention in senior secondary school chemistry. Published Ph.D. Thesis, University of Nigeria, Nsukka.

Oluwasegun, M.O., & Olabode, T.O. (2020). Effects of virtual laboratory instructional strategy on secondary school students' learning outcomes in physics practical. *International Journal of Scientific and Research Publications, 10* (4), 406-413.

Omwirhiren, E.M. (2015). Enhancing academic achievement and retention in senior secondary school chemistry through discussion and lecture methods: A case study of some selected secondary schools in Gboko, Benue State, Nigeria. *Journal of Education and Practice*, *6* (21), 155 – 161.

Raju, S. (2017).Recent status of education, employment and empowerment of women in West Bengal. *International Journal of Scientific and Research Publications, 7*(1), 265 – 269.

Robbins, F.M. (2021).Ultimate electronics: Practical circuit design and analysis. circuitab,com/cu5584wxrenxw

Rosen, J.D., & Kelly, M.A.(2020). Epistemology, socialization, help seeking, and gender-based views in in-person and online, hands-on undergraduate physics laboratories, Phys. Rev. Phys. Educ. Res. **16**, 020116 (2020).

Shedrack, T., & Nduudee, N. J.(2023).Teachers' qualification and secondary school students' academic performance in Emohua Local Government Area, Rivers State. *FNAS Journal of Mathematics and Science Education, 5*(1), 124 – 132.

Theodore, N. E., Mumuni, A.A.O., & Nwanekezi, A.U. (2016). Enhancing chemistry students' retention of redox reaction concept through intervention with advance organizers. *British Journal of Psychology Research, 4*(4), 34-46.

Umukozi, A. , Yadav, L. L., & Bugingo, B.J.(2023). Effectiveness of virtual labs on advanced level physics students' performance in simple harmonic motion in Kayonza District, Rwanda. *African Journal of Educational Studies in Mathematics and Sciences*, 19 (1), 85- 96.

Uzezi, J.G., & Zainab, S. (2017). Effectiveness of guided inquiry laboratory experiment on senior secondary schools students' academic achievement in volumetric analysis. *American Journal of Education Research, 5*(7), 717-724.