

## **EFFECT OF VIRTUAL CHEMISTRY LABORATORY SOFTWARE (VCLS) ON SECONDARY SCHOOL STUDENTS' ACHIEVEMENT IN ACID-BASE TITRATIONS EXPERIMENT**

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### **Abstract**

*Poor funding, high cost of maintaining standard chemistry laboratory compared to the virtual laboratory software, fragile and expensive apparatuses and costly reagent necessitated the need to determine the effect of Virtual Chemistry Laboratory Software (VCLS) on Lagos State secondary school chemistry students' achievement during acid-base titrations experiment. The influence of gender was also examined. Four null hypotheses guided the study. It was a quasi-experimental research design of 2x2x2 non-randomized factorial matrix with a sample of 164 (104 females and 60 males) and average age of 14 years participated in the study. Three research instruments were used for data collection. Data were analysed using two-ways ANOVA. The results show a significant effect of Virtual Chemistry Laboratory Software (VCLS) over the Conventional Chemistry Laboratory (CCL) on secondary school chemistry students' achievement during acid-base titrations experiment such that the female students slightly performed better than the males in both the VCLS and CCL. There was also slight interaction effects of VCLS and gender on chemistry students' achievement during acid-base titrations experiment but there was no influence of school type during acid-base titrations experiment. The study concludes that there will be need to expose all students to VCLS and this may remove stress, provide students with adaptive challenge, curiosity, immediate feedback, competition, discovery, clear objectives and self-expression. The study suggests that the examining bodies like National Examinations Council (NECO) and West Africa Examination Council (WAEC) should introduce VCLS in all their internal and external examinations which is economical and saves student from endangering themselves with hazardous chemicals like Con. H<sub>2</sub>SO<sub>4</sub>.*

### **Introduction**

Chemistry is an experimental and practical oriented core subject that is required in the study of many courses such as medicine, biochemistry, microbiology, pharmacy, and engineering among others (Okafor & Uzoechi, 2012). Science students therefore need sound knowledge of chemistry and its

underlying skills to contribute meaningfully to national development. Several studies have shown abysmal failures of some secondary school chemistry students' during internal and external examinations due to poor teaching methods and inadequate consumables and non-consumables during practical activities (Chief Examiners Reports, 2014; Okafor & Uzoechi, 2012; Njoku, 2007).

Other factors identified include inadequate and poor utilization of laboratory resources, poor foundation of science, and digital illiteracy (Okafor & Uzoechi, 2012; Kelly & Jones, 2008 and Ardac & Akaygun 2004). Jescheke, Richter & Zorn (2010) investigated the use of virtual laboratory in science and mathematics and found their correlation with gender and internet awareness with males positively favoured. In addition, Okafor's (2016) study showed that secondary school students' achievement in chemistry is determined by their learning styles. The need to determine the influence of school location on students' achievement was also suggested. Josephsen & Kristensen (2006) posited that using simulated laboratory will enhance students learning outcomes in inorganic chemistry. Kerr, Rynearson and Kerr (2004) emphasised on teaching secondary school chemistry students innovative educational practices, using virtual laboratory which is experimentally based. Experimental chemistry is fundamental during practical works since it inspires students and enhances their problem-solving skills (Okafor, 2017).

However, acid-base titrations is the main chemistry experiment commonly assessed in secondary school external practical but its activities are usually carried out in the conventional laboratory, which in most schools are non-existent or inadequately equipped (Chief Examiners Reports, 2014; Njoku, 2007). Thacker (2007) and Yang & Heh (2007) suggested the use of internet virtual laboratory that complements the conventional laboratory which improves science instructions. Some researchers' also viewed on-line-instructional procedures as very effective on students with diverse needs in the learning of science (Thacker, 2007; Yang et. al. 2007; Okebukola, 2006). Kerr et. al. (2004) supported the use of Virtual Chemistry Laboratory Software(VCLS) as innovative intervention strategy for teaching secondary school science practical which does not involve hazardous experiments on the students and synergises students of differing academic abilities to achieve their common objectives during practical as well as building self-confidence and self-esteem among the learners. Thacker (2007) stated that the use of virtual laboratory could develop students' scientific ideas and promote achievement in them as independent thinkers.

Other studies reported that chemistry achievement cannot be effectively achieved if the use of virtual laboratory software is not efficiently infused in the secondary school system (Jescheke et. al. 2010; Thacker, 2007). This is a limitation that demands alternative educational technologies (Zacharia, 2005; Kerr et.al. 2004).

In schools, laboratory experiments can be carried out virtually, using computer simulations or animations (Okafor, 20017; Gambari et.al 2013). Virtual laboratory is an interactive environment without real laboratory tools meant for creating and conducting simulated experiments (Kelly & Jones, 2008). It provides students with tools and materials that are put up on computer, in order to perform experiments saved on CDs or on web site (Okafor 2012). Kelly & Jones (2008) study showed that virtual laboratory improved students' performance in high school biology.

Josephsen & Kristensen (2006) investigated undergraduate chemistry response to SimuLab computer-based learning environment. Its result revealed undergraduates likeness to simulated programme that enhanced their experience and knowledge on chemical reactions of common inorganic compounds.

In many public secondary school chemistry laboratories, consumables and non-consumables are grossly inadequate and many times non-existence. This compelled the researchers to undertake the study of this nature in determining the effect of VCLS on secondary school chemistry students' achievement during acid-base titrations experiment and to find out the extent to which gender and school type could influence students' achievement during acid-base titrations experiment.

Chemistry practical is fundamental in making teaching and learning of science meaningful and interesting. During Senior School Certificate Examinations (SSCE), practical chemistry is examined separately with allotment of high percentage marks to it (Chief Examiner's Report, 2014; Njoku, 2007). Njoku (2007) lamented students' failure rate during May/June West African Examination School Certificate chemistry practical. The West African Examination Council (WAEC) revealed, among other things, that candidates' performance was not encouraging due to students' non-familiarity with the use of laboratory equipment (Chief Examiner's Report, 2014). One of the problems faced at the secondary schools during chemistry practical is unavailability or inadequacies of apparatuses, chemicals and technical staff for the conduct of the practical. This is because of poor funding and high cost of maintaining standard chemistry laboratory compared to the virtual laboratory software.

In most cases, the apparatuses are fragile, expensive and involve frequent replacement of prepared chemical reagents, especially the hazardous consumables periodically (Okafor and Uzoechi, 2012). Gambari, Olumorin and Yusuf (2013) suggested the use of computer jigsaw in cooperating learning for improved performance in chemistry achievement, while Ardac et.al (2004) suggested the use of multimedia instructions for improved understanding in chemistry. These observed deficiencies in the conventional laboratory can be surmounted with the virtual laboratory software to determine its effect on chemistry students' achievement during acid-base titrations experiment. It also ascertained the influence of gender and school type on students' achievement. Four null hypotheses were tested in the study which included the following:

- There is no significant effect of VCLS on secondary school chemistry students' achievement during acid-base titrations experiment.
- There is no significant influence of gender (female and male) on secondary school chemistry students' achievement during acid-base titrations experiment.
- There is no significant interaction effects of VCLS and gender (male and female) on secondary school chemistry students' achievement during acid-base titrations experiment.
- There is no significant influence of school type (coeducational and single schools) on secondary school chemistry students' achievement during acid-base titrations experiment.

## **Method**

The research design adopted was quasi experimental whereby intact classes were subjected to treatment (VCLS) and control (conventional laboratory) on a 2x2x2 non-randomized factorial matrix. In Education District IV of Lagos State, Six (6) Senior Secondary Schools (SSS) were purposively selected based on the availability of functional chemistry laboratory, computer room with internet facilities, and chemistry and computer teachers with master's degree respectively. In each of these schools, SS II chemistry students in all the arms participated in the study because they were not preparing for any external examinations and had earlier been exposed to acid-base titrations in the conventional laboratory. All the arms of SSII chemistry students in the three schools with internet facilities were subjected to Virtual Chemistry Laboratory Software (VCLS) (experimental group), while all the arms of SSII chemistry students in the other three schools without internet facilities were exposed to Conventional laboratory (control group). In addition, all the chemistry teachers of the intact classes participated in the

study. This was to control for threat variables and to uphold internal consistency of the sample. The sample comprised of 164 (104 females and 60 males) with average age of 14 years. Three research instruments were used in data collection and they included; Teaching Manual on Virtual Chemistry Laboratory Software (TMVCLS); Teaching Manual on Conventional Chemistry Laboratory (TMCCL) and Chemistry Alternative to Practical Test (CAPT). Validity and reliability of CAPT were determined by its administration to SSII students of two secondary schools in Education District IV that did not participate in the study. Their responses were computed using Kuder-Richardson formular 20 to ascertain its reliability index and the value of  $r=0.89$  was obtained, showing evidence of internal consistency. Students in the experimental group were taught, using the TMVCLS while others in the control group were taught using the TMCCL. Before the treatment, pre-test on acid-base titrations structured in an alternative to practical format was administered to the two groups (the experimental and control groups respectively). After the treatments, the respondents were allowed to carry out the practical activities on acid-base titrations experiment, using VCLS, while the control group did theirs, using conventional laboratory experiment.

Thereafter, post-test using CAPT was administered on the two groups to determine their achievement. There scores were computed and analysed using mean, standard deviation and Analysis of Variance (ANOVA).

## Result

**Table 1: TWO-WAY ANOVA Results of Tests Between-Subjects Effect (VCLS on Secondary School Chemistry Students' Achievement during Acid-Base Titrations Experiment)**

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected model	611.154 <sup>*</sup>	6	101.859	24.707	.000
Intercept	2200.176	1	2200.176	533.683	.000
Pretest	200.525	1	200.525	48.640	.000
Treatment	75.737	1	75.737	18.371	.000
Gender	40.964	1	40.964	9.936	.002
School Type	7.960	1	7.960	1.931	.167
Treatment* gender	29.751	1	29.751	7.216	.008
Treatment*school type	501	1	501	.121	.728
Gender*school type	<b>.000</b>	<b>0</b>			
Treatment* Gender*school type		<b>.000</b>	<b>0</b>		
Error	647.253	157	4.123		
Total	34774.750	164			
Corrected total	1258.407	163			

Table 1 shows that the treatment variable (VCLS) has significant effect than the control group (CCL) on secondary school chemistry students' achievement during acid-base titrations experiment with a significant value of 0.00 which is less than 0.05. In addition, the absolute F-value of 24.70 is greater than the Tabulated F-value of 4.28. Considering the statistics rule which states that when the Absolute Value is greater than the Critical Tabulated Value, the null hypothesis should be rejected. Thus, there is a significant effect of VCLS on secondary school chemistry students' achievement during acid-base titrations experiment than the CCL control variable.

**Table 2: Descriptive Statistics of Influence of Gender (female and male ) and School Type on Secondary School Chemistry Students' Achievement during Acid-Base Titrations Experiment.**

Treatment (N)	Gender	School Type	Mean	Std. Deviation	VCL	
CCL	Male	Coeducational	14.7143	2.14460	42	
		Total	14.7143	2.14460	42	
	Female	Coeducational	14.8077	2.01036	26	
		Single	16.2353	1.93546	34	
	Total	Total	15.6167	2.07766	60	
		Coeducational	14.7500	2.07957	68	
	TOTAL	Male	Single	16.2353	1.93546	34
			Total	15.2451	2.14193	102
		Female	Coeducational	10.5833	3.91171	18
			Total	10.5833	3.91171	18
		Total	Coeducational	13.6250	2.25663	24
			Single	13.6000	1.73660	20
Total		Total	13.6136	2.01409	44	
		Coeducational	12.3214	3.39444	42	
Total		Single	13.6000	1.73660	20	
		Total	12.7339	3.00780	62	
TOTAL		Male	Coeducational	13.4750	3.35401	60
			Total	13.4750	3.35401	60
	Female	Coeducational	14.2400	2.19285	50	
		Single	15.2593	2.25024	54	
	Total	Total	14.7692	2.27046	104	
		Coeducational	13.8227	2.89779	110	
Total	Single	15.2593	2.25024	54		
	Total	14.2957	2.77854	164		

**NOTE: VCLS: Virtual Chemistry Laboratory Software; CCL: Conventional Chemistry Laboratory**

Data in Table 1 shows a significant value of 0.002 which is less than 0.05 on the influence of gender on secondary school chemistry students' achievement during acid-base titrations experiments. According to the statistics rule, when the significant value is less than .05 the null hypothesis is rejected. Hence, there is significant influence in the mean CAPT (achievement) scores of female and male students during acid-base titrations experiment. It is observed that students exposed to VCLS did better than those exposed to CCL. This is evidenced in Table 2, where the females slightly performed better than the males in both VCLS and CCL respectively. This means that gender has slight influence on secondary school chemistry students' achievement during acid-base titrations experiment with the females excelling on the CAPT.

The result for the interaction effect of VCLS (treatment) and gender (male and female) on secondary school chemistry students' achievement during acid-base titrations experiment from Table 1 shows that VLCS and gender interact together to significantly influence secondary school chemistry students' achievement during acid-base titrations experiment with a significant value of 0.008 which is less than 0.05 hence ,the null hypothesis which states that there is no significant interaction effects of VCLS and gender (male and female) on secondary school chemistry students' achievement during acid-base titrations experiment is upheld.

From Tables 1 and 2 it was observed that the school type (coeducational and single schools) does not have any influence on secondary school chemistry students' achievement during acid-base titrations experiment has a significant value of .167 which is greater than .05 and also an absolute F-value of 1.93 which is less than the critical tabulated value 161 and according to the statistics decision rule which states that the null hypothesis should be rejected when the significant value is less than 0.05 and also when the absolute F-value is greater than the tabulated value hence school type does not have a significant effect on the (coeducational and single schools) on secondary school chemistry students' achievement during acid-base titrations experiment.

## **Discussion**

The findings of this study showed that there was significant effect of Virtual Chemistry Laboratory Software (VCLS) over the Conventional Chemistry Laboratory (CCL) on secondary school chemistry students' achievement during acid-base titrations experiment such that the female

students did better than the males on both the treatment and control groups respectively.

The finding contradicts the work of Jescheke et.al (2010) who found the use of virtual laboratory in science and mathematics gender biased by favouring males positively. This is an evidence that females can compete favourably with males and even excel better than them in all spheres of life. Obviously, the better performance of females in both VCLS and CCL pedagogies could foster their problem-solving skills than the male counterpart (Okafor 2017).

The significant effect of VCLS corroborates with the claim of Kerr et.al.(2004); Thacker (2007) and Jescheke et. al. (2010) who asserted that innovative educational practices promote classroom learning of science as well as the use of virtual laboratory which can develop students' scientific ideas, promote their achievement and thereby making them independent thinkers when efficiently infused in the secondary school system. The finding also supports Okafor (2012) who posited that teaching with ICT tools contributes meaningful to learning outcomes among secondary school chemistry students. The study was equally found not to be in consonance with Okafor (2016) which explained that chemistry students' achievement is influenced by their perceived learning styles.

There was no significant influence of school type on secondary school chemistry students' achievement during acid-base titrations experiment but a significant interaction effect of VCLS and gender was slightly observed. This is in support of the argument that on-line educational programme brought to the classroom during teaching and learning brings innovation that favours females in the learning process (Kerr et. al. (2004).

## **Conclusion**

It is important to state that the conventional chemistry laboratory has been entrenched in many Nigerian secondary schools at all level. This method has not yielded positive results, considering the challenges teachers envisage in chemistry emanating from non-availability of basic reagents required during acid-base titration experiment, teacher centeredness during practical and students' passiveness. This therefore reflected in the students' performance during mock examinations as observed in the schools sampled for this study. It is interesting to reflect that VCLS removes stress, provide students with adaptive challenge, curiosity, immediate feedback, competition, discovery, clear objectives and self-expression. However, meeting the learning needs of all the chemistry students, irrespective of gender, is complex and highly demanding but the techniques and methods employed would compel students

to alter any misconceptions, enhance positive achievement, promote gender equity, thereby helping students to learn meaningfully during chemistry experiment.

### **Recommendations**

Based on the findings of the study, the following recommendations are suggested.

1. The use of Virtual Chemistry Laboratory Software (VCLS) should be made compulsory in all the secondary schools in Nigeria for preparing secondary school chemistry students during practical.
2. The Examining bodies like National Examinations Council (NECO) and West African Examination Council (WAEC) should introduce VCLS to all their internal and external examinations. This is highly economical in the use of reagents and saves student from endangering themselves with hazardous chemicals like Con.  $H_2SO_4$ .
3. Chemistry teachers should be trained professionally on how to conduct quantitative and qualitative experiments meaningfully with ease using VCLS.
4. Students should not be overwhelmed with the fun inherent in VCLS whenever teachers are conducting experiment with them.
5. School management should provide standby generators and internet facilities to ensure effective application of VCLS in various schools that will enable chemistry students succeed in chemistry experiment.
6. Principals, States and Federal Government should sponsor secondary school chemistry teachers to conferences and workshops where innovations in the teaching of chemistry are demonstrated with examples. They should also be encouraged to learn how to develop softwares for effective and efficient teaching and learning of chemistry.
7. Secondary school chemistry classrooms and laboratory should be very friendly to encourage equitable achievement among females and males in the school setting.

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